TM 1-414

WAR DEPARTMENT

TECHNICAL MANUAL

AIRCRAFT WOODWORK

December 22, 1942

TECHNICAL MANUAL No. 1–414 } WAR DEPARTMENT, WASHINGTON, December 22, 1942.

AIRCRAFT WOODWORK

SECTION I

GENERAL

1. General.—*a.* Recent developments in methods of fabricating wooden aircraft and wooden aircraft parts have eliminated some of the major objections to the use of wood as an aircraft structural material. As a result, wood is now being used extensively in the construction of certain types of aircraft, especially light training and reconnaissance aircraft, and also for gliders. This manual is intended for use as a guide in the repair and maintenance of aircraft employing wood as a structural material.

b. The information included in this manual is to be construed as of a general nature and should not be regarded as a substitute for specific instructions in Technical Orders, specifications, manufacturers' handbooks, or other authoritative sources. Methods of construction naturally will vary with different types of aircraft, as will the various repair and maintenance procedures. Accordingly, manufacturing specifications and Technical Orders should be adhered to when such are provided. Only approved types of materials should be used and all repairs should conform to original design requirements with respect to strength, mechanical operation, and other factors which contribute to the general airworthiness of the aircraft.

495091°—43——1

SECTION II

CHARACTERISTICS OF WOOD

2. Tree structure.—*a.* Examination of the cross section of a log (fig. 1) discloses four distinct regions or sections: the bark, the sap-

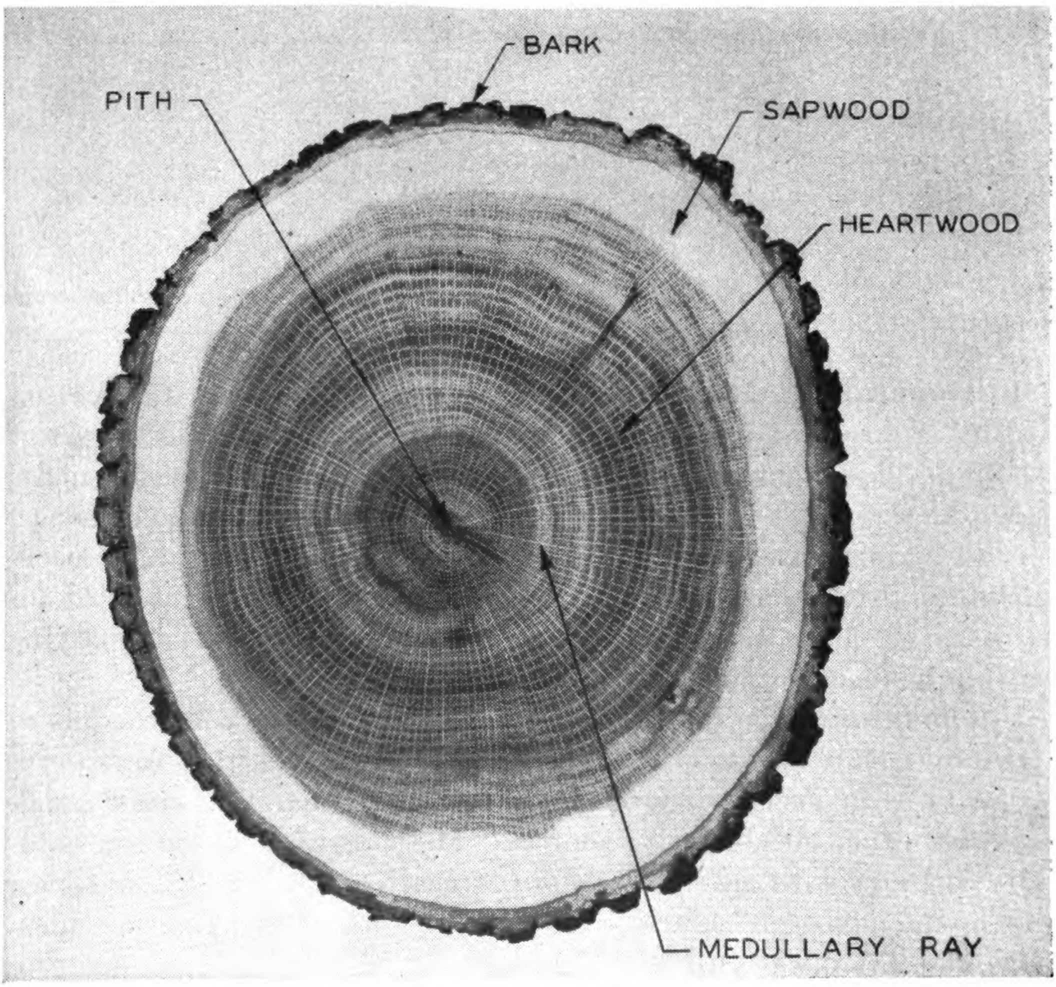


FIGURE 1.—Cross section of a log.

wood (light-colored layer next to the bark), the heartwood (darker wood inside the sapwood), and the pith (small, soft core of the tree). As a general rule, the sapwood is lighter in color than the heartwood. However, in spruce, basswood, and others, there is very little if any

difference between the color of the heartwood and the sapwood. After timber is seasoned, the heartwood is usually more resistant to decay, stain, mold, and to the attack of certain insects, than is the sapwood; whereas, in the living tree the opposite is true.

b. The bark serves as a protective covering for the tree. The cells of the sapwood function mainly in the movement and storage of food. Some of these cells are alive but most of them are dead, acting only as passages for sap and adding to the strength of the trunk. The cells of the heartwood are dead and function only in supplying strength to the trunk.

3. Classification.—Woods are generally grouped as hardwoods or softwoods. Hardwoods come from broadleafed trees and include ash, birch, basswood, mahogany, maple, walnut, etc. Softwoods come from trees with needlelike or scalelike leaves (evergreens), commonly known as conifers, and include fir, pine, cypress, and spruce. In some instances the terms are not descriptively exact since yellow pine, generally classified as a softwood, is in reality harder than basswood, which is classified as a hardwood. However, as a result of long usage, the terms have become definitely established.

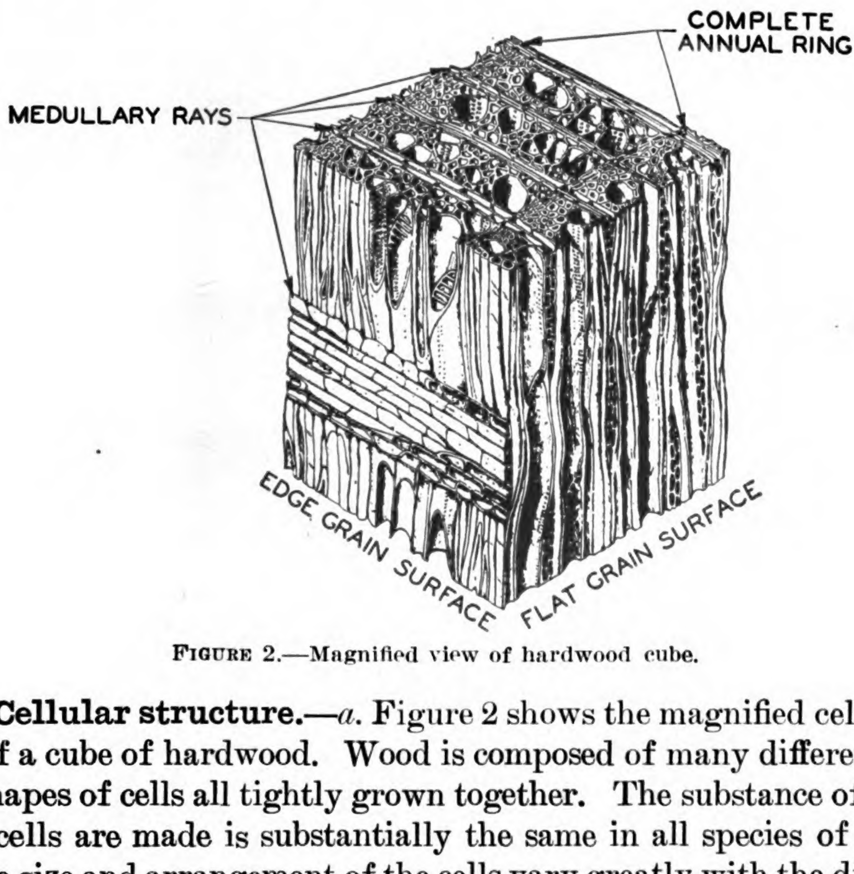


FIGURE 2.—Magnified view of hardwood cube.

4. Cellular structure.—*a.* Figure 2 shows the magnified cell structure of a cube of hardwood. Wood is composed of many different sizes and shapes of cells all tightly grown together. The substance of which these cells are made is substantially the same in all species of woods, but the size and arrangement of the cells vary greatly with the different woods. It is this difference in the size, thickness of cell walls, and

arrangement of cells that accounts for the great variation in the weight and strength of woods.

b. (1) The hardwoods differ from the softwoods as a class in the presence of larger cells, constituting pores, scattered among the smaller ones which are mostly fibers. In many hardwoods the pores may be seen distinctly without magnification, as small holes on smoothly cut cross sections and as fine grooves on planed longitudinal surfaces.

(2) In softwoods, the bulk of the wood is composed of fibrous cells which may be seen on a smoothly cut magnified cross section.

5. Medullary rays.—Medullary rays, also known as pith rays, are rows of cells which extend radially from the center of the tree (see figs. 1 and 2). They vary greatly in size, being so small in many woods as to be invisible without magnification. In oak, however, they are very large and account for the large silvery patches so characteristic of this wood when it is quarter-sawed.

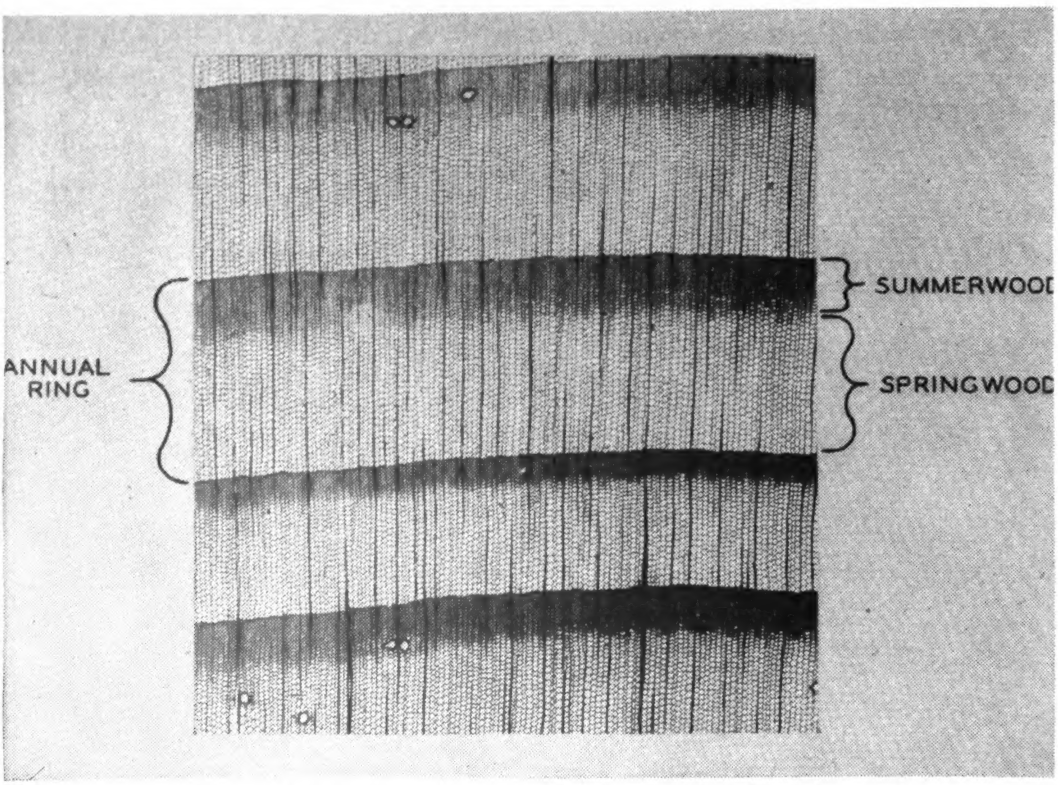


FIGURE 3.—Magnified view of annual ring.

6. Springwood and summerwood.—Each annual ring (fig. 3) is composed of two regions or parts: the springwood and the summerwood. Springwood is the wood formed on the inner side of the annual ring during the early part of the growing season. It is usually more porous, softer, weaker, and especially in conifers, lighter in color than the summerwood, which is formed in the outer part of the annual ring

during the latter part of the growing season. In some woods the distinction between these two parts of an annual ring is very clear, whereas in others the springwood merges into the summerwood with no distinct dividing line.

7. Grain.—*a.* The recommended usage of the term "grain" is that it be confined to describing the direction in which the fibers run, that is, straight, spiral, interlocked, wavy, or curly grain. However, the term is also loosely used to refer to annual rings as coarse, fine, even, edge, and flat grain (see par. 11 for edge grain and flat grain); and to the relative size of pores and fibers as open grain and close grain.

b. Wood employed in aircraft construction is straight-grained within limits of deviation as set forth in the specification for the particular lumber used.

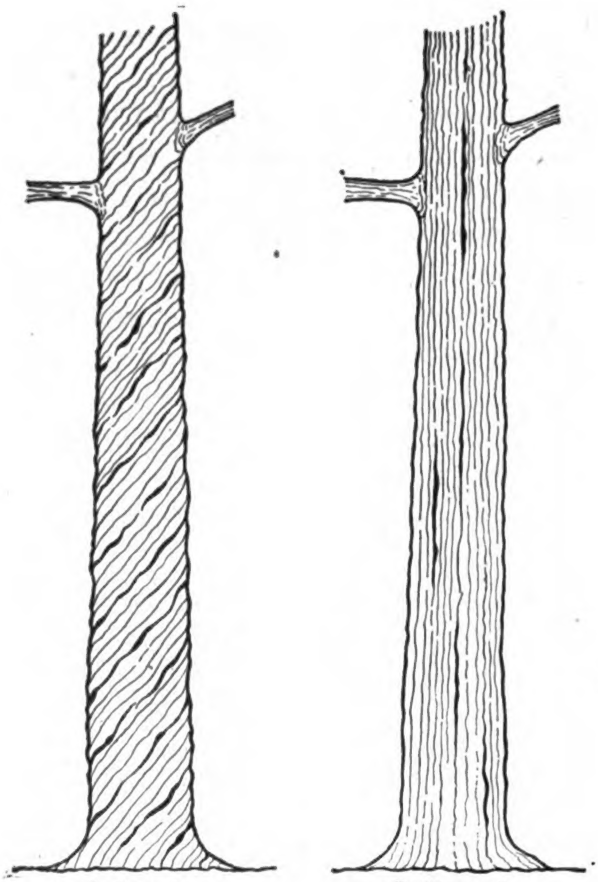
8. Common defects in wood.—Irregularities which occur in or on wood which may lower its strength are regarded as defects. Common defects in wood are described below.

a. Cross grain.—Cross grain may be regarded as any deviation of the grain from parallelism with the axis of a piece of wood. It may be classified as spiral, diagonal, or a combination of both.

(1) *Spiral.*—(*a*) Spiral grain occurs when the fibers take a spiral course in the tree trunk, as if the tree had been twisted (fig. 4①). On a truly tangential (plain-sawed or flat grain) surface (fig. 5) the oblique direction of the checks, resin ducts (brownish hairlike lines in softwoods), and pores (visible in many hardwoods) indicate the direction of the fibers. Normally, this direction is parallel to a line drawn through the apexes of the "flowers" formed by the annual rings on a plain-sawed surface; however, if spiral grain is present the fibers run at an angle to this line. If sufficient pores, resin ducts, or checks are not visible, the direction of the grain can be determined by the direction in which free-flowing ink spreads or fibers pull up. The presence (but not the slope) of spiral grain is indicated on quarter-sawed faces when the planer tears out chips in such a way as to show that the grain runs into the piece instead of parallel to its axis.

(*b*) Spiral grain, when pronounced, is objectionable because it weakens the wood, tends to twist the lumber during seasoning, and usually produces a rough surface when quarter-sawed faces are planed against the grain.

(2) *Diagonal.*—(*a*) Diagonal grain in lumber is a defect produced entirely by sawing and results when the direction of sawing is not parallel to the bark. Spiral grain is frequently confused with diagonal grain; however, there is no relationship between the two since spiral grain is a defect of growth. On a truly edge grain surface, diagonal grain is easily detected by the slope of the annual rings.



① Spiral. ② Normal.

FIGURE 4.—Spiral and normal tree growth.

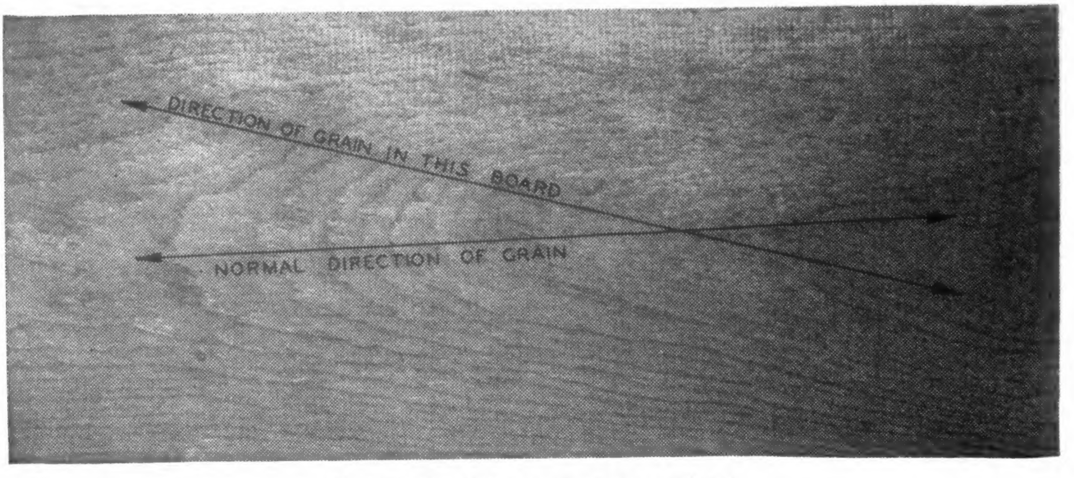


FIGURE 5.—Spiral grain in lumber.

On the flat grain (plain-sawed) surface (fig. 6), its presence (but not the slope) may be detected by a line drawn through the apexes of the "flowers."

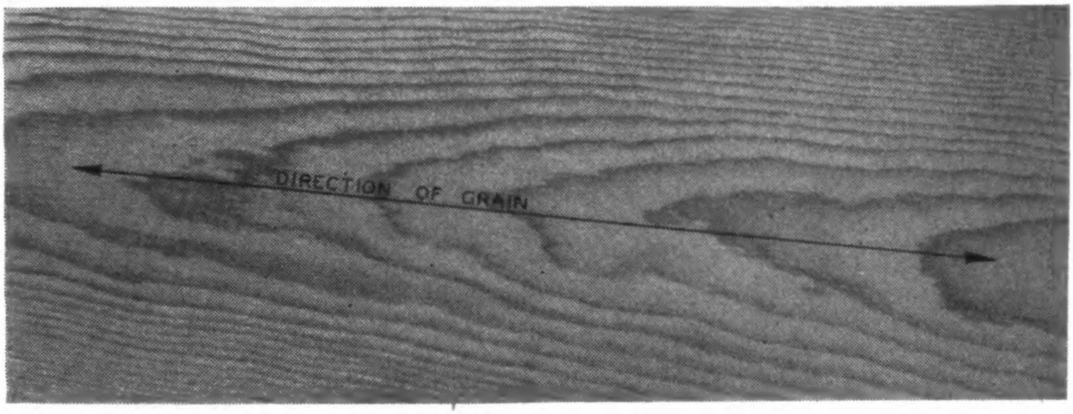


FIGURE 6.—Diagonal grain in lumber.

(*b*) Diagonal grain, when pronounced, is objectionable because of its weakening effect on lumber and the chipped appearance of the surface which results when planing the plain-sawed faces against the grain.

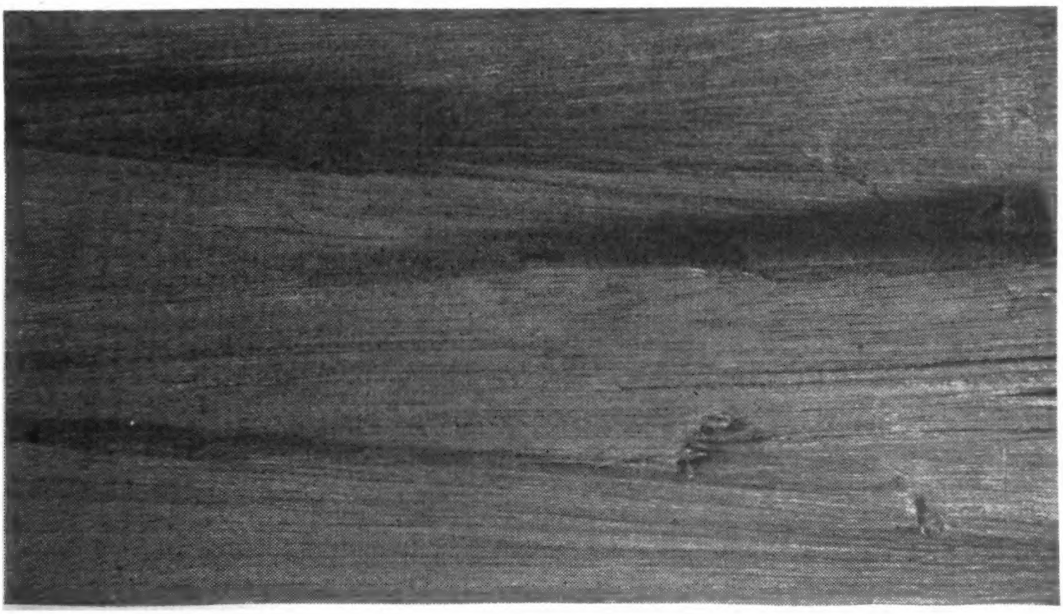
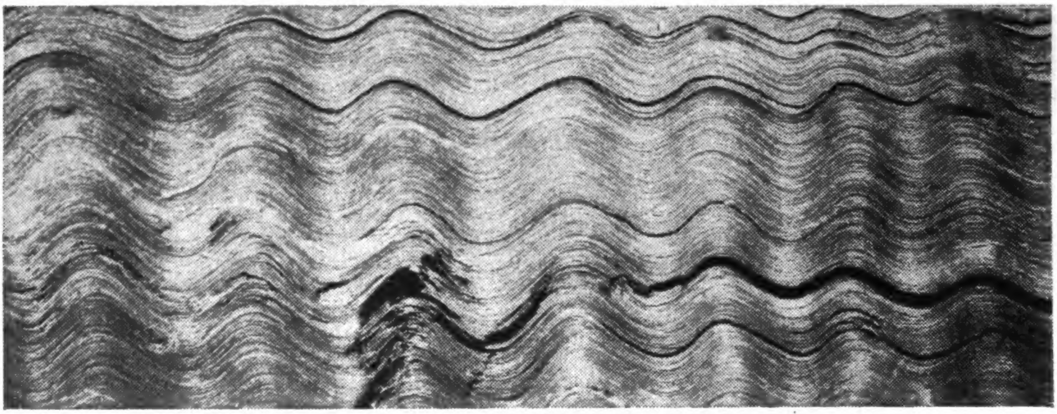


FIGURE 7.—Interlocked grain.

(3) *Interlocked.*—(*a*) Interlocked grain (fig. 7) is produced when the fibers are inclined in one direction in a number of annual growth rings, then gradually reverse and are inclined in an opposite direction in succeeding growth rings, and then reverse again. Interlocked grain is confined largely to hardwoods, seldom being found in softwoods.

(*b*) Interlocked grain is a common cause of warping, especially in plain-sawed lumber, and causes difficulty in planing.

(4) *Wavy and curly.*—Wavy grain and curly grain result when the wood fibers assume contorted courses in parts of trees or throughout the whole trunk and branches. The contortions may be regular as in wavy grain (fig. 8 ①), or very irregular as in curly grain (fig. 8 ②).



① Wavy. ② Curly.

FIGURE 8.—Wavy and curly grains.

b. Knots.—(1) A knot is the base of a limb embedded in the tree trunk. Normally, a knot starts at the pith and increases in diameter from the pith outward as long as the limb is alive. Occasionally it starts some distance from the pith. As long as the limb remains alive its fibers interlace with those of the trunk, producing an intergrown knot. After the limb dies the wood formed in the trunk makes no further connection with it, but grows around it, producing an encased knot. When the dead limb breaks off, the stub heals over and the distortion of grain in successive growth layers lessens with increasing diameter of the trunk until, finally, clear wood with normal grain is produced.

(2) A sound, tight knot, solid across its face, is fully as hard as the surrounding wood, shows no sign of decay, and is so fixed by growth or position that it will firmly retain its place in the piece. A knot cut through transversely is known as a round knot (fig. 9); one cut through obliquely is known as an oval knot (fig. 10); and one cut through lengthwise is known as a spike knot (fig. 11).

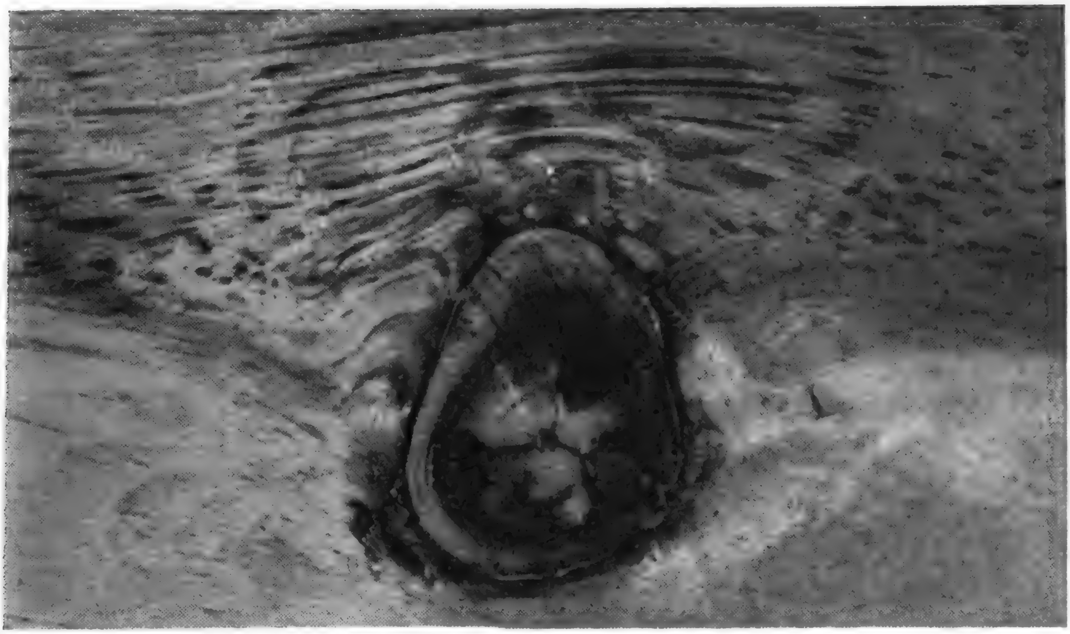


FIGURE 9.—Round knot.

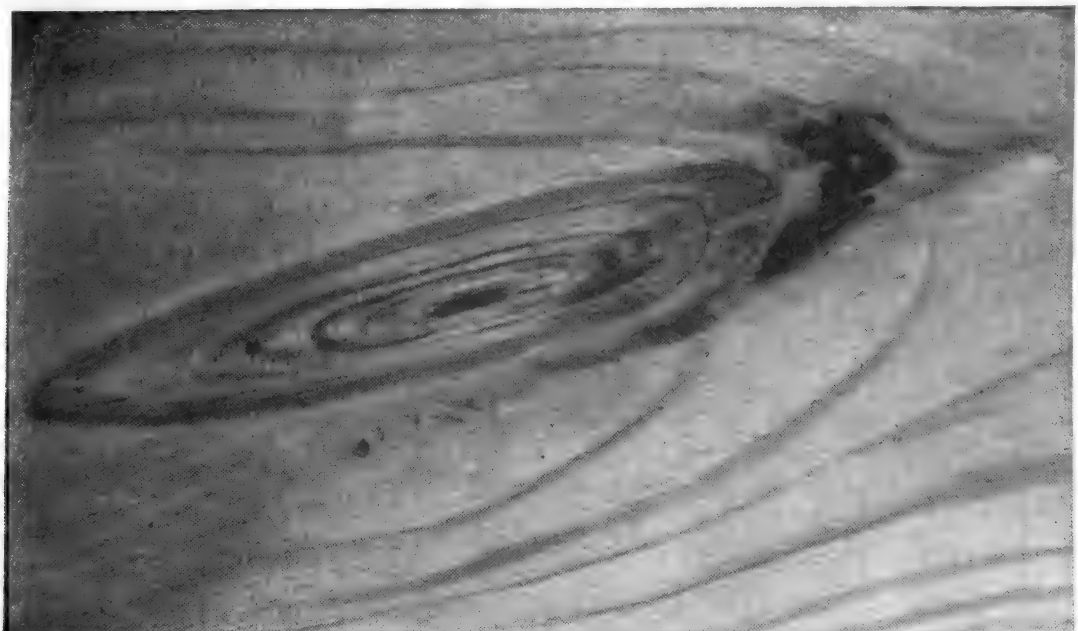


FIGURE 10.—Oval knot.

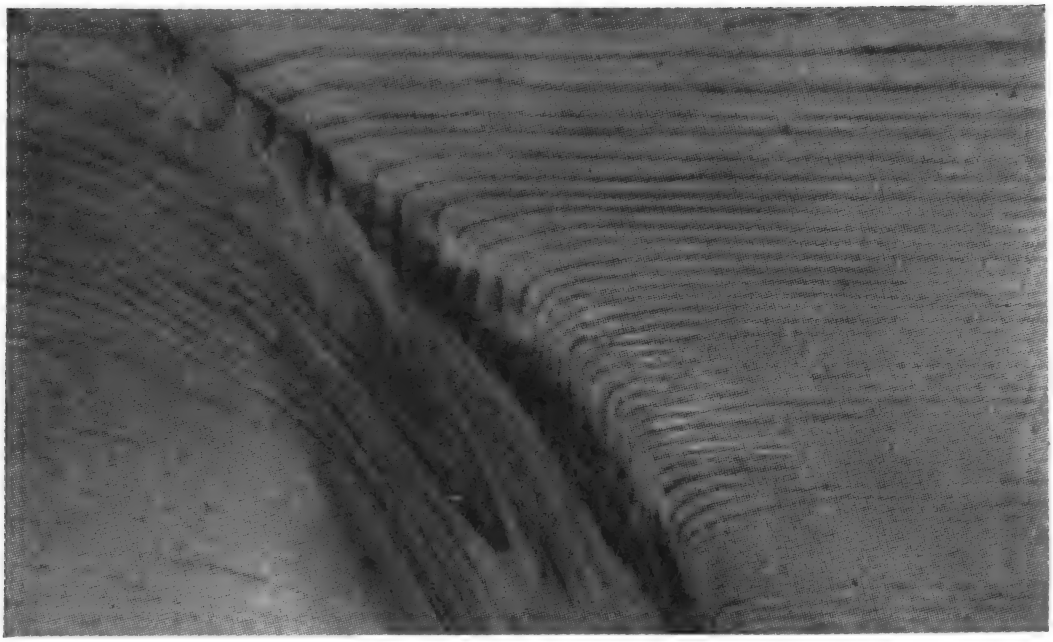


FIGURE 11.—Spike knot.

(3) Knots are objectionable mainly because of the distortion and discontinuity (caused by encased knots) of the grain they produce, thereby weakening the wood. Knots also cause irregular shrinkage and difficult working of lumber. Loose knots are likely to drop out, and in resinous species pitch often exudes more freely from a knot than from the clear wood.

c. Indented growth rings.—In certain softwoods the annual rings, as seen on a cross section, are sometimes successively indented along a radial line (fig. 12). In a tangential plane, indented rings produce

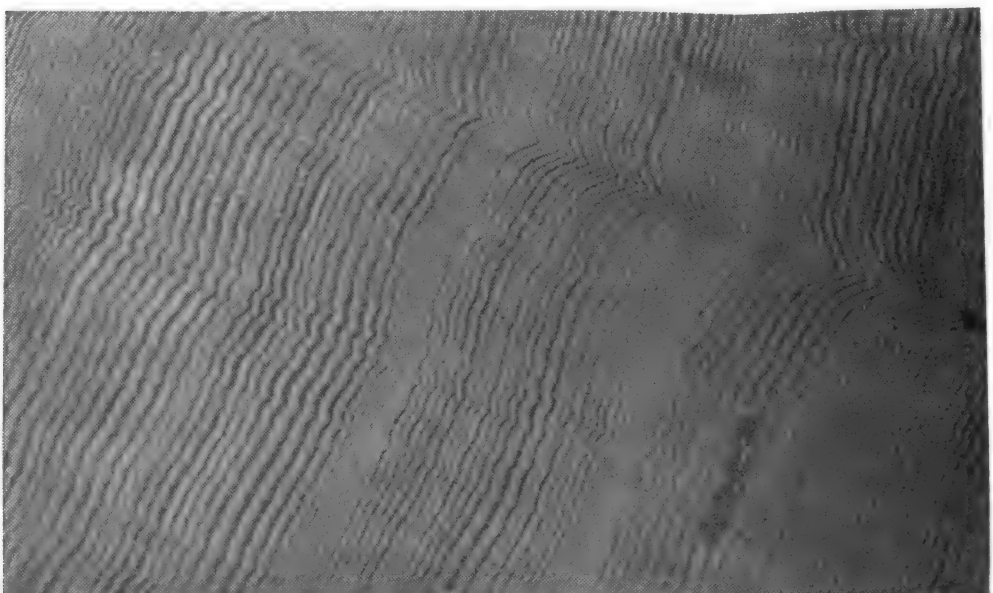
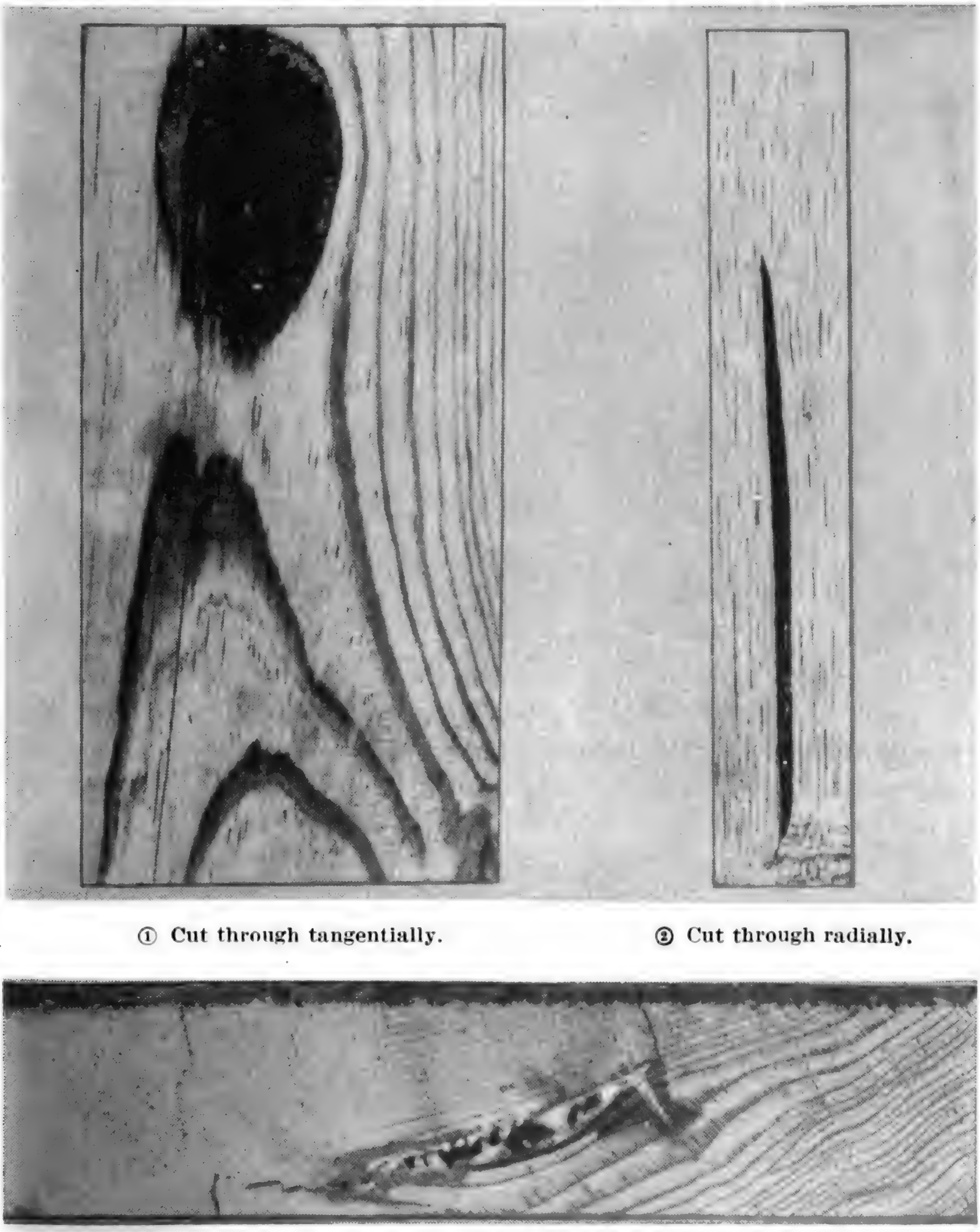


FIGURE 12.—Indented growth rings.

noticeable blemishes but cause no distortion of grain. The presence of indented rings is not regarded as serious in members of fair size or ordinary proportions.



① Cut through tangentially. ② Cut through radially.

③ Cut through transversely.

FIGURE 13.—Pitch pocket.

d. Pitch pockets.— (1) Pitch pockets (fig. 13) are well-defined openings, usually longer than wide, between annual rings. They contain more or less free resin and occasionally contain bark.

(2) Pitch pockets are objectionable because they may weaken small members and also may exude resin, especially when the wood becomes warm.

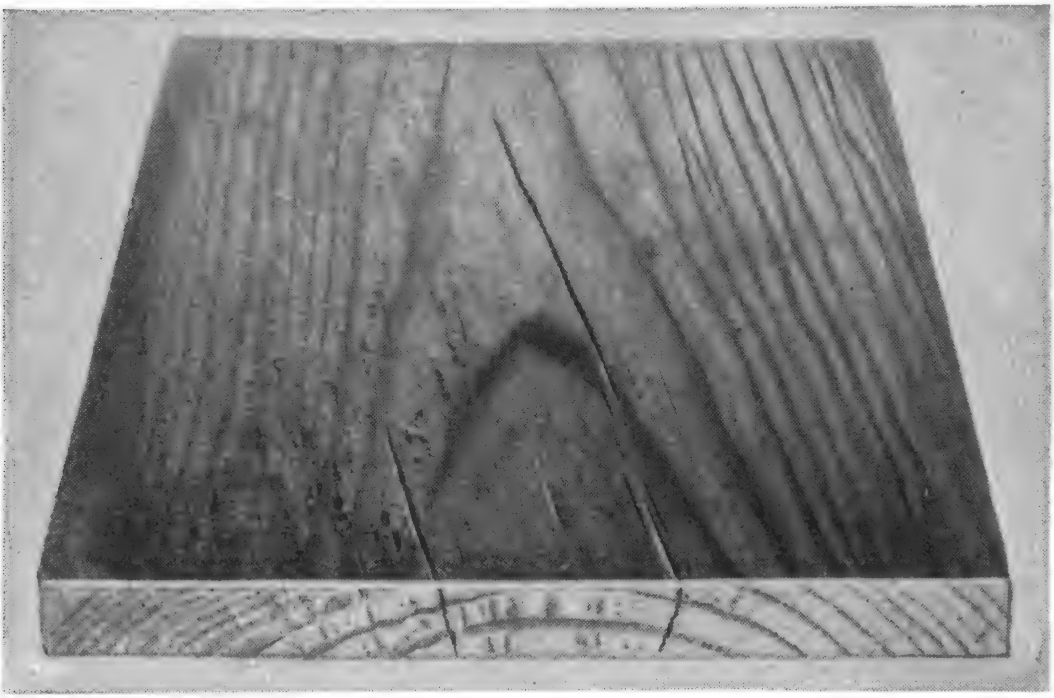


FIGURE 14.—Checks in lumber.

e. Checks, shakes, and splits.—(1) *Causes.*—(*a*) A check (fig. 14) is a longitudinal crack generally extending radially across the annual rings. Checks are usually caused by uneven shrinking in seasoning.

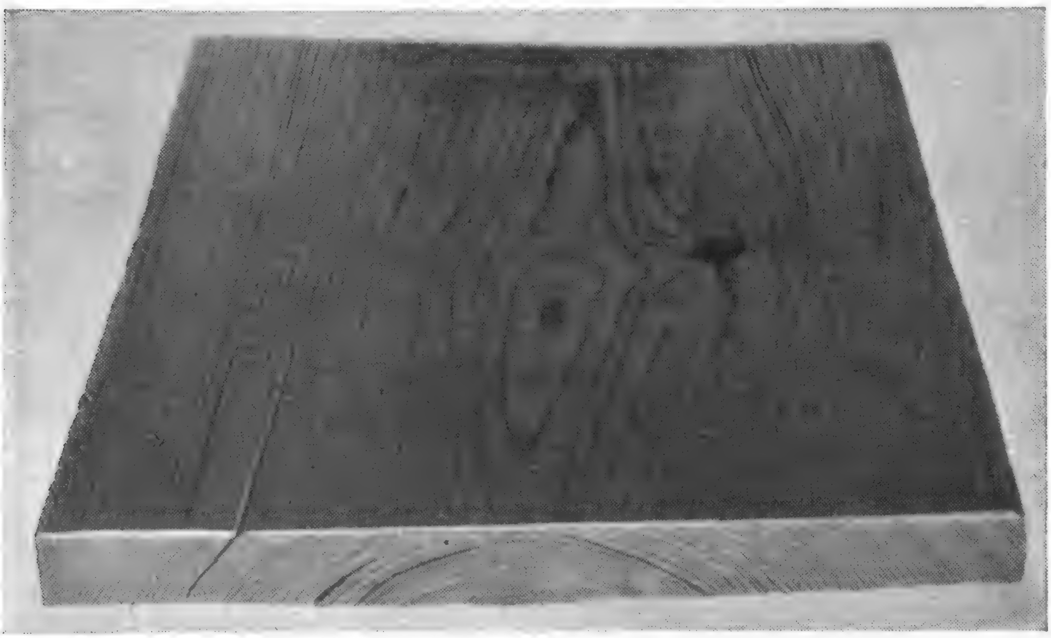


FIGURE 15.—Shakes in lumber.

(*b*) A shake (fig. 15) is a longitudinal crack extending, in general, between two annual rings. Shakes occur in green timber and may become accentuated in seasoning.

(*c*) A split is a longitudinal crack caused by rough handling or other artificially induced stresses. When splits take a radial or tangential course they are not readily distinguishable from checks or shakes.

(2) *Effects.*—Checks, shakes, or splits may seriously weaken members. The weakening influence of such defects is usually greater than the visible openings would indicate.

f. Stains and decays.—All woods, to a greater or less extent, are subject to stains and decays. Stains not associated with decay have, as a rule, little effect on strength; whereas decay affects the strength of wood even in the early stages. Many stains and decay are caused by fungi which grow in the wood. Development of fungi is dependent upon relatively high moisture content of wood, suitable temperature, an abundant supply of food substances, and a supply of oxygen. Lumber kept entirely dry (or entirely immersed in water) will not decay. Decay is prevented by proper kiln-drying or air-drying immediately after sawing, and thereafter by keeping it dry in storage. Keeping airplanes and parts in a dry place when not in use will usually prevent decay. Lack of air circulation when combined with high atmospheric humidity affords an ideal condition for the growth of wood-inhabiting fungi.

(1) *Stains.*—Stains in wood occur as specks, spots, streaks, or patches of varying intensities of color. The so-called "blue" stains, which vary from blue to bluish black and brown, are the most common, although various shades of yellow, orange, purple, and red are sometimes encountered.

(2) *Decay.*—(*a*) Incipient decay usually appears as a discoloration, in some cases pronounced, in others so faint as to be practically invisible. It rarely ends abruptly or evenly but usually fades out into one or more irregular streaks. Such streaks usually extend not more than 3 or 4 feet along the grain of the wood beyond the typical decay. The discoloration due to decay as observed on a cross section may be distinguished from the normally darker bands of heartwood by observing whether or not the darkening follows closely a definite group of annual rings; if so, the color variation is probably normal. If, on the contrary, the discoloration pattern is independent of the ring pattern, the color change may be a symptom of defect. Typical or late stages of decay are easily recognized because the wood has then undergone definite changes in color and properties. The rotted wood may be brown or white in color. There are also intermediate types between the white and brown rots.

(*b*) In the early stages of decay, the crushing strength parallel to the grain of the wood is affected but little, whereas the shock resistance is reduced markedly. In the final stages of the development of decay, little or no strength remains in the wood.

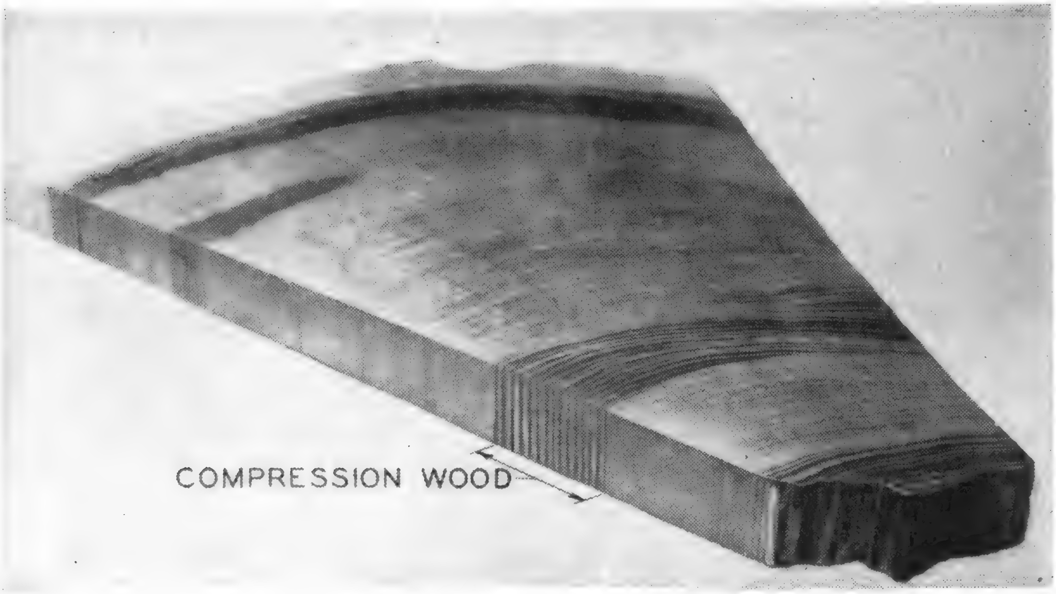


FIGURE 16.—Compression wood.

g. Compression wood.—Compression wood (fig. 16) is a type of abnormal growth frequently occurring in the under side of leaning trees and limbs of softwood species. In comparison to normal growth, it is distinguished by wider growth rings, usually eccentric, and includes what appears to be an exceptional proportion of summerwood growth. The contrast in color between springwood and summerwood, however, is usually less in compression wood than in normal wood. Compression wood has a high longitudinal shrinkage and is low in strength for its weight. When compression wood is present with normal wood, unequal endwise shrinkage causes bowing and crooking. Material containing compression wood is not generally permitted in aircraft construction.

h. Compression failures.—Compression failures in wood (fig. 17) are caused by excessive bending of the standing tree from wind or snow, by felling trees across logs, rocks, or other objects, by rough handling of logs and sawed stock, and by excessive stresses in service. They appear as wrinkles or streaks substantially at right angles to the grain across the face of a board. Whereas some compression failures are so pronounced as to be unmistakable, others are difficult to detect. Tilting of the wood with respect to the line of vision or source of light may help to make compression failures visible.

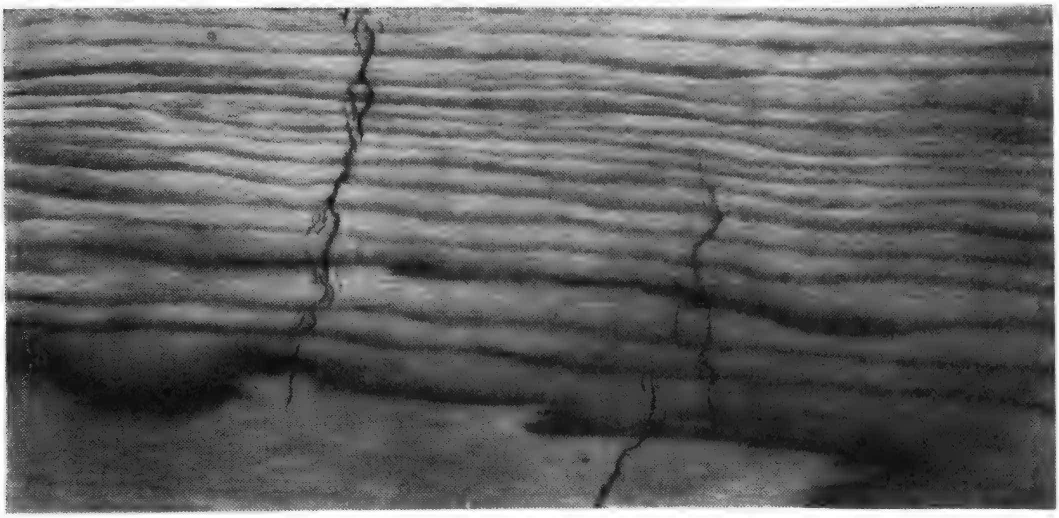


FIGURE 17.—Compression failure in lumber.

Even those failures not readily apparent to the eye may seriously reduce the bending strength of the wood and its shock resisting ability. Wood containing compression failures is not permitted in aircraft construction.

i. Brashness.—The term "brash," frequently used interchangeably with the term "brittle," indicates a lack of toughness when used to describe wood or failures in wood. Brash wood (fig. 18), upon being bent, usually fails suddenly and completely at small deflection, producing few or no splinters. Brash wood in the conifers is usually of very rapid growth, whereas in the hardwoods it is generally of very slow growth.

9. Factors affecting strength.—The most important factors which influence the strength of wood, other than defects, are the spe-

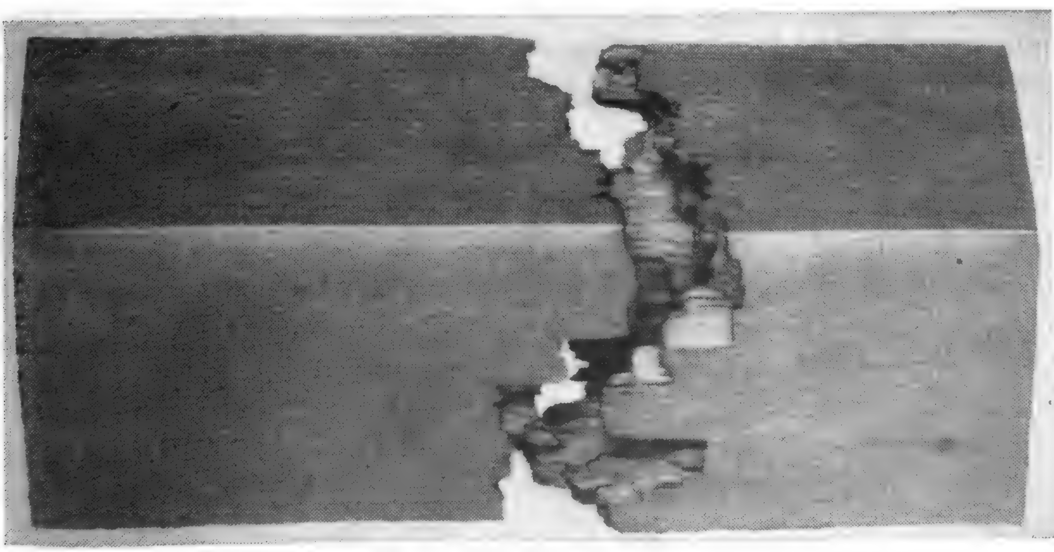


FIGURE 18.—Brash wood.

cific gravity, or density, and the moisture content. These factors cause variations in the properties of the same species as well as in different species of wood. However, in the finished stock these variations are largely eliminated by proper specifications and inspection.

a. Specific gravity.—The best single criterion of the strength of wood other than mechanical test is its specific gravity or weight per unit volume, the weight being taken when the wood is completely dry. Determination of density, together with careful consideration of such defects as knots, cross grain, compression failures, compression wood, and decay, are now largely used as means of selecting airplane woods. Other factors which at times have some influence on selection are amount of summerwood, rate of growth, and region of growth. When wood is judged wholly on the basis of weight and appearance, some of the material accepted may be too low in strength, particularly tensile strength, and hence in shock resistance, to prove satisfactory. Such material is brash and is rejected whenever found. Frequently brash material is also of low density. It is material which is brash but still of satisfactory weight and good appearance which causes much trouble in airplane construction. Two of the most frequent causes of brashness in material of this kind are compression failures and decay, even in the very early stages before apparent to the eye. After some experience, a mechanic should be able to eliminate stock which is exceptionally light in weight by comparison with stock of satisfactory weight. Of two pieces of stock of the same species and size, both free from visible defects and stored under like conditions, the heaviest piece normally has the highest strength.

b. Moisture content.—Moisture is contained in saturated wood as free water within the cell cavities and as hygroscopic moisture within the cell walls. The free or excess water has no effect as such on volume or strength; however, after it has been drawn off and water begins to come from the cell walls, the wood shrinks and at the same time increases rapidly in strength of load bearing properties. Those that represent toughness or shock resistance sometimes actually decrease as the wood dries, because dried wood will not bend as far as green wood before failure, toughness being dependent upon both strength and pliability. In drying, the greatest shrinkage occurs in the direction of the annual growth rings (tangentially); about one-half to two-thirds as much across these rings (radially), and as a rule, very little along the grain (longitudinally). In drying, internal stresses are set up which tend to cause checks and other defects. The more the wood is dried, the greater is the tendency of these defects to develop.

Section III

LUMBER AND PLYWOOD

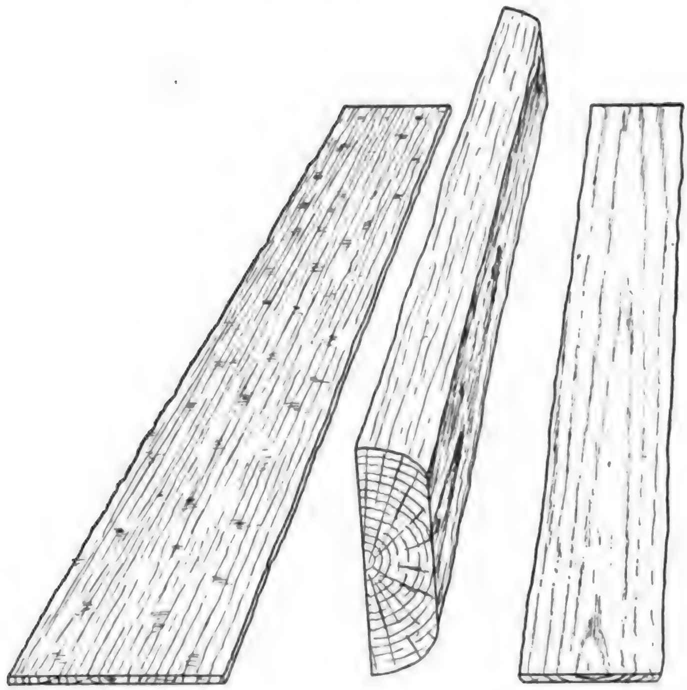
10. Lumber.—*a.* Lumber is the product of the saw and planing mill. Lumber intended for specific uses is further sawed, passed lengthwise through a standard planing machine, crosscut to length, matched, seasoned, and graded.

b. A large tree when sawed into lumber yields boards of widely varying quality. Lumber grades divide the product of the tree into several graduations, each having a relatively narrow range in quality, which permits selection for a definite use and purpose. The grade of a piece of lumber is based on the number, character, and location of such features as knots, pitch pockets, etc. The best grades are free or practically free from these features.

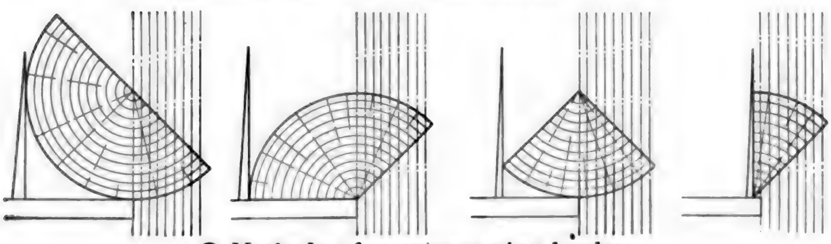
c. Lumber selected for aircraft use must pass Government inspection in accordance with specifications for each species of wood. These specifications are designed to authorize the most liberal tolerance of defects in wooden parts used in aircraft consistent with maintenance of structural strength. The particular specification for each wood should be consulted for defect limitations and other requirements.

11. Plain-sawed and quarter-sawed lumber.—*a.* When a log is sawed into boards at the sawmill it may be either plain-sawed or quarter-sawed (fig. 19①). With respect to the annual rings there are three distinct cutting planes: crosswise, exposing the transverse or end grain surface; lengthwise along any of the radii of the annual rings, exposing the radial or so-called quarter-sawed or edge grain or vertical grain surface; and lengthwise, tangent to any of the annual rings, exposing the tangential or so-called plain-sawed or flat grain surface. Usually, so-called quarter-sawed or edge grain lumber is not cut strictly along the radii of the annual rings (fig. 19②). Often in plain-sawed boards the surfaces next to the edges are far from being tangent to the rings.

b. Quarter-sawed lumber, in general, shrinks and swells less in width, and also twists, cups, slivers, surface checks, and case-hardens in seasoning less than plain-sawed lumber. It also wears more even-



① Quarter-sawed and plain-sawed boards.



② Methods of quarter-sawing lumber.

FIGURE 19.—Plain- and quarter-sawed lumber.

ly. Plain-sawed lumber, on the other hand, is less expensive because it requires less time and involves less waste in cutting. Round or oval knots which may occur in plain-sawed boards weaken the board less than spike knots which usually occur in quarter-sawed lumber.

12. Seasoning and storage of lumber.—*a. Seasoning.*—(1) Lumber must be properly dried and stored if the parts to be made from it are to have their proper weight and strength, and hold the desired size and shape. The effects of changes in moisture content on the strength of wood and shrinkage is discussed in paragraph 9*b*. The moisture content of green lumber is reduced by natural air-drying, by kiln-drying, or by a combination of both. Air-drying consists of exposing the lumber for a sufficient length of time. The proper piling of lumber for air seasoning or temporary storage previous to kiln-drying is important. Green or partially dry stock is subject to various forms of deterioration such as staining, decay, check-

ing, and insect attack. Proper piling of stock tends to reduce deterioration to a minimum.

(2) Lumber is kiln-dried to reduce moisture content more quickly than in air-drying, and to reduce the moisture content to a lower point than can ordinarily be attained in air-drying. In addition, if stain or decay organisms or wood boring insects are present, the lumber will be sterilized and the borers killed. The lumber in a kiln is heated, and evaporation is caused by means of hot air passing through the piles.

b. Storage.—Lumber, if kept dry and free from insects, may be stored either indoors or outdoors since both methods are equally effective.

(1) The following instructions cover outdoor storage:

(*a*) A well-drained area free from weeds, decayed or insect infested woods, etc., should be chosen for piling the lumber. In laying out an area for arrangement of lumber piles, at least 4 feet of space is provided between the sides and 8 feet between the ends of lumber piles.

(*b*) Support for piling may be either foundations, walls, or rows of individual piers constructed of masonry or creosoted timbers spaced approximately 6 feet apart, so that a pile of lumber approximately 12 feet wide will have not less than one row of supports longitudinally under each side and one down the middle. The foundation must be sufficient in length to support the full length of the longest timber to be piled. If composed of individual piers, each row should have a creosoted sill extending the full length of the pile. The foundation is sloped so that the piled lumber has a longitudinal slope of 1 inch to the foot. The height of the lower end of the foundation should be at least 18 inches from the ground. Cross beams or skids spaced 2 feet apart are placed across the longitudinal sills (or foundation walls) and should be of creosoted timber unless heartwood of cypress, cedar, or redwood is used, in which case only points of contact on masonry need be creosoted.

(*c*) The lumber is piled so that the slope is lengthwise of the boards. Each board is laid on its flat side with a space of approximately 1½ inches between each board. Stickers 1¼ by 4 inches of adequate length and free from stain, decay, insects, etc., are placed crosswise between each layer of lumber. These stickers are spaced so that they are in vertical alinement with the cross beams supporting the pile. Stickers are placed also at the ends of the layers. To afford protection from the weather, a roof is laid over the lumber pile, elevated 6 inches from the top layer of boards and with the same amount of slope.

(*d*) Hardwoods and softwoods are piled separately, with only one kind of lumber in each pile if the storage space permits.

(*e*) The height and width of a lumber pile is determined by the available storage space.

(2) When storage space is available, lumber may be stored indoors in a dry, well-ventilated building, using stickers between each layer and spaces between the edges of the boards in the same manner as specified for outdoor storage. Ample ventilating space should also be left between the floor and the bottom of the pile, and at least 2 feet of space provided between the pile and any adjacent wall of the building. Lumber that has been thoroughly kiln-dried may be piled tight for indoor storage if storage space is limited; however, the bottom of the pile must also be well above the floor.

(3) A sufficient quantity of lumber to fulfill normal requirements should be stored in a heated building for a period of 2 or 3 weeks prior to use, at a temperature approximating that of the shop in which it will finally be used. This lumber should be piled with liberal spaces to allow free circulation of air.

13. Damage to lumber by insects.—*a*. Certain hardwoods, such as ash, oak, and hickory, and other hardwoods to a lesser extent, are subject to damage by the powderpost beetle, which is a reddish brown to nearly black flying beetle. The primary damage is caused by the larvae of this beetle, which are yellowish white grubs. These burrow through the sapwood in all directions. The activities of this beetle may be identified by the small, round worm holes in the surface of the wood from which a very fine powder is discharged. The damage to the interior of the wood may often be more extensive than indicated by the exterior evidence. The destructive action is progressive, as the larvae are more numerous as they propagate from year to year, until there are no longer enough food elements left in the lumber to support life. Only the sapwood of the hardwoods is attacked, although in seeking an exit, the mature beetle may sometimes burrow through the heartwood. All new stock should be inspected to prevent the introduction of wood infected with beetles.

b. If evidence of the presence of this beetle is found, the following instructions should be observed in order to prevent further damage:

(1) Inspect all lumber semiannually, especially stocks on hand 2 or more years, preferably in November and February, and sort out and burn all wood showing evidence of attack.

(2) Issue the oldest stocks first.

(3) Prevent the accumulation of refuse material in which the beetles may breed.

(4) Use only heartwood piling stickers.

14. Plywood.—*a. Definition.*—Much confusion has been caused by the indiscriminate use of the terms "veneer" and "plywood." The term "veneer" is restricted to the relatively thin sheets of wood cut with special veneer machinery from the surface of a log revolving in a massive lathe or by slicing or sawing from the log, known respectively as rotary cut, sliced, and sawed veneer. "Plywood" on the other hand, refers to the combination of several plies or sheets of veneer glued together.

b. Properties of solid wood compared with plywood.—It is not always possible in a given use to proportion a board or a solid panel so as to develop the necessary strength in every direction and, at the same time, to utilize the full strength of the wood in all directions of the grain. If the strength properties of wood were the same in all directions with reference to the grain, wood would be very desirable for many parts now made of other materials. As it is, the tensile strength of wood may be 20 times as high parallel to the grain as perpendicular to the grain. In the case of shear the strength is reversed, the shearing strength perpendicular to the grain being much greater than parallel to the grain. The low shearing strength parallel to the grain makes difficult the utilization of the tensile strength of wood along the grain, since failure will usually occur through shear at the fastening before the maximum tensile strength of the wood is reached. As compared with solid wood, the chief advantages of plywood are its approach to equalization of strength properties along the length and width of the panel, greater resistance to checking and splitting, and less change in dimensions with changes in moisture content. These advantages are obtained by alternating the direction of grain in the successive plies.

c. Usage.—Plywood is used in the fabrication of structural or highly stressed parts of aircraft, such as wing and fuselage coverings, wing rib webs, etc.

d. Construction.—(1) (*a*) All plies except the core or center ply are of the same species, thickness, and direction of grain, but occur in pairs placed on opposite sides of the core to produce symmetrical construction. All veneer of any one layer is of the same thickness. The grain of all plies is at right angles to the grain of adjacent plies and to the edges of the plywood.

(*b*) Two-ply diagonal planking is constructed of two plies of veneer of equal thickness, with the direction of grain of one ply at right angles to the grain of the other ply, and having the direction of the grain of both plies at approximately 45° with the longitudinal axis of the panel.

(2) On at least 90 percent of the area of each sheet of veneer the slope of grain from the edge of the sheet should not be steeper than 1 inch to 10 inches.

(3) (*a*) Plywood should be smooth, flat, and free from blisters, wrinkles, laps (one piece overlapping the other rather than making a smooth butt joint), checks, open joints, and other defects. Stain or discoloration due to gluing is considered a defect. This is because it is impossible to have satisfactory secondary gluing with cold resin glue when the plywood is partially impregnated with resin. If panels have been sanded, they should be sanded on both sides. Unequal sanding is considered a defect. Sanding should not reduce the thickness of the face plies more than 10 percent of their nominal thickness.

(*b*) Veneer used in aircraft plywood must be free from brash wood, pitch pockets, holes, pronounced compression wood, compression failures, checks, patching in any form, or incipient form of decay. The following defects, which may appear singly (one type only) or as a combination of more than one type of defect provided the number of defects does not exceed the limits specified for any one type of defect, are permissible in sheets of veneer that are otherwise of high quality: sound, tight knots up to 3/8 inch in diameter, provided they are not more frequent than two in any 1 square foot; sound, tight burls, not more frequent than two in any 1 square foot; pinworm holes, not more frequent than two in any 1 square foot; streaks of mild forms of compression wood, not totaling more than 10 percent of the width of the sheet and in no case wider than 1/2 inch.

e. Splitting resistance.—Plywood permits fastening with nails or screws close to the edges because it offers much greater resistance to splitting than solid wood. In removing nails from plywood some care must be used to pull them straight out or nearly so, because splintering of the outside ply may result if the nails are pulled or pried out at an angle.

f. Storage.—Plywood is stored as follows:

(1) Plywood is always removed from the crates or shipping boxes and properly stored as soon as practicable; any shipment which has become wet is unpacked and stored immediately.

(2) Where available storage space permits, stocks are segregated according to the kinds of wood.

(3) Plywood is stored indoors in a dry, well-ventilated building, piled flat on suitable concrete or creosoted stringers 6 inches high in order to permit ventilation. All edges are exposed to permit inspection and adequate ventilation. Dry plywood may be piled tightly.

If wet or subjected to excessive humidity, it is piled with stickers ½ inch square between each piece and spaced as follows:

(a) Plywood ¼ inch thick or over—24 inches.

(b) Plywood ⅛ inch to ¼ inch—12 inches.

(c) Plywood less than ⅛ inch—8 inches.

(4) Shellac or varnish applied to the edges of stored plywood assists in preventing deterioration from excessive humidity. However, this method of protection is not ordinarily necessary and should not be employed unless it is evident that storage conditions require this additional precaution.

15. Laminated wood.—A piece of wood built up of plies or laminations that have been joined, usually with glue, and where the grain of all plies is parallel, is called laminated wood. The plies are usually too thick to be classified as veneer. The properties of parallel grain constructions are essentially the same as those of solid wood but laminated members, if well constructed, are usually more uniform in strength properties and less likely to change shape with variations in moisture content. Laminated construction is used extensively for producing curved members and is discussed in section VII.

16. Aircraft woods.—*a. General.*—(1) Relatively few species of wood are now used for aircraft construction, although many species which are not used have properties equal to those used. Obviously, certain species are much better than others for use in airplane construction. Among the foremost factors which have led to the present limitation of suitable woods are a satisfactory combination of desirable properties, ease of fabrication, uniformity of quality, facility in gluing, ease of drying, availability, and cost.

(2) The general appearance of wood is not sufficiently accurate as a means of identifying the various kinds of wood. There are specific differences, however, which are most useful in wood identification. These differences consist of the cellular structure, color, odor, taste, weight, hardness, and in some cases, exudation of resin or oil.

(3) The characteristic structure is usually seen to best advantage on a smoothly and freshly cut end surface, across rings of average width. The color of wood in some cases is sufficient for its identification. Heartwood and sapwood usually differ in color. However, changes in color take place in wood on long exposure to light and air. Odor cannot be described with any degree of accuracy. The taste of wood often resembles the odor, although exceptions occur. Both odor and taste are more pronounced in the heartwood than in the sapwood. Since the weight of wood varies with the moisture content, its weight

aids best in identification when it is oven-dry. Identification of wood by hardness is affected by density and moisture content. However, the resistance of wood to indentation or cutting (especially across the grain) is useful in distinguishing species with considerable differences in hardness. Exudations of resin and pitch pockets are common in woods containing resin ducts.

b. Hardwoods.—(1) *White ash.*—The heartwood of white ash is grayish brown (occasionally with a reddish tinge), and the sapwood, which varies in thickness from less than an inch to several inches, is white. Ash is somewhat similar in appearance to oak and hickory. It ranks high in weight, strength, hardness, and shock resistance, retains its shape well, wears well, is flexible, and is easy to bend. It does not take glue as readily as spruce. Ash is used for sheet metal dies and forms, for propellers, bearing blocks, wing leading and trailing edges, and reinforcing for structural members.

(2) *Basswood.*—The heartwood of basswood is creamy brown and the sapwood is creamy white. Basswood has a slight characteristic odor even when dry. It is light in weight, low in strength, straight-grained, easily workable, and can be nailed without splitting. It is a satisfactory low density species for use in plywood, and also for filler blocks and corner blocks.

(3) *Birch.*—The woods of the yellow birch and sweet birch are very similar and, generally, no distinction is made between the two. The sapwood is almost white and the heartwood is light to moderately deep reddish brown. The annual rings are rather indistinct. The wood of both is heavy, hard, stiff, and strong, has good shock resisting ability, but is low in natural resistance to decay. The wood does not split easily, and glues well. Sweet and yellow birch are used for propellers and in plywood construction for faces and cores.

(4) *Mahogany.*—Mahogany is a lustrous reddish brown wood which turns darker after exposure to light. It is a heavy wood and varies greatly in weight. The pores are distinctly visible; numerous pores contain dark amber-colored gum. The growth rings are defined by light-colored lines and are widely variable in width. The wood is easy to work and glue. Mahogany is a basic structural material, used mainly in plywood form for rib gussets, webs, skin covering, and propellers.

(5) *Hard maple.*—The heartwood of hard maple is light reddish brown and its sapwood is white with a slight reddish brown tinge. The annual rings are defined by a thin reddish layer usually conspicuous on dressed longitudinal surfaces, and the rays appear as reddish brown flakes on radial faces. The grain is usually straight

but occasionally curly and wavy grains occur. The wood is heavy, hard, strong, and stiff, has good resistance to shock, and wears well under abrasion. It has moderate shrinkage, good gluing properties, and although hard, does not dull tools excessively. It is used in plywood construction, for propellers, jigs, bearing blocks, and miscellaneous other uses where an extremely hard wood is desired.

(6) *Oak.*—There are numerous species of oak which commonly are divided into two groups: red oak and white oak. The heartwood of white oak is grayish brown; that of the red oak usually has a reddish tinge. The sapwood is white. The pores in the heartwood of white oak are, for the most part, filled with a growth called tyloses which renders the wood less permeable to liquids than that of red oak. The rays are quite pronounced in the sawed lumber. The wood is heavy, hard, stiff, and strong. It is used for propellers and test clubs.

(7) *Yellow poplar.*—The heartwood of yellow poplar is a yellowish brown with a greenish tinge; the sapwood is white. The annual rings are limited by light-colored lines. The wood is slightly heavier than spruce, and while rather low in shock resisting ability, has good working qualities, retains its shape well, and is comparatively free from checks and shakes. It is easy to nail because it does not split readily, and is easy to glue. It is regarded as a satisfactory substitute for spruce. Such substitution involves no necessity for engineering changes. Poplar is used in plywood construction (core and faces) and also as a substitute for spruce.

(8) *Black walnut.*—The heartwood of black walnut varies from light to dark brown; the sapwood is lighter in color. The annual rings are fairly distinct for the pores in the springwood decrease in size gradually as the springwood merges into the summerwood. The color and distinct pores are usually sufficient to distinguish black walnut from other woods. The wood is heavy, strong, stiff, and has the quality to retain its shape under varying conditions of moisture. It is easily worked and glues satisfactorily. It is used for propellers and may be used as a substitute for mahogany plywood.

c. Softwoods.—(1) *Spruce.*—In the white spruce and red spruce, the heartwood is as light-colored as the sapwood, whereas in Sitka spruce the heartwood has a light reddish tinge, rendering it slightly darker than the sapwood. Split or smoothly dressed tangential surfaces of Sitka spruce usually have numerous slight indentations which give it a pocked appearance. Red, white, and Sitka spruce possess excellent strength properties, with a high ratio of strength to weight. They may be glued with facility. Spruce is a basic structural wood used for highly stressed parts such as spars, struts, and compression

ribs; it is also used for cap strips and in the construction of plywood. Spruce is considered the standard of comparison for suitability of other softwoods for use in aircraft construction.

(2) *Balsa.*—Balsa is light gray in color and frequently stained with bluish streaks. There are no annual rings, although an occasional fine growth ring may be seen. The most characteristic feature of balsa is its extreme lightness in weight, which is approximately half that of cork. Balsa is not used where strength is a factor. It is used for streamlined forms, fairing strips, and as a core material for plywood in some cases.

(3) *Port Orford cedar.*—The sapwood of this species is not clearly defined from the heartwood, which is very pale brown in color and is highly resistant to decay. The wood has a spicy odor. It is moderately light in weight (heavier than spruce) and equals or exceeds the strength properties of spruce. It is used in the construction of plywood and as a substitute for spruce.

(4) *Douglas fir.*—The heartwood of Douglas fir has a reddish hue and a characteristic odor when worked. The annual rings are made distinct by a conspicuous band of summerwood. The species from the Pacific coast is heavier than spruce, the strength qualities of which it equals or exceeds, though it is more likely to develop checks in manufacture or service than spruce. Quarter-sliced fir is used in the construction of plywood; it is also used as a substitute for spruce.

(5) *Hemlock.*—The sapwood of western hemlock is not readily distinguished from the heartwood, which is very pale brown with a reddish tinge. Narrow bands of summerwood clearly define the annual rings. Western hemlock is slightly heavier than spruce and equals or exceeds that species in most of its strength properties. It is usually straight-grained, nonresinous, and glues satisfactorily. It is used as a substitute for spruce.

(6) *White pine.*—Eastern and western white pine are very similar in the character of the wood. The heartwood ranges from creamy brown to light reddish brown, especially reddish at knots. The wood is moderately light in weight, soft, straight-grained, and has a distinct resinous odor. The wood is lighter than spruce but lower in strength properties, particularly in hardness and shock resistance. White pine is easily worked, takes nails easily without splitting, and may be glued satisfactorily. It is not used for structural units but is used for patterns and mock-ups.

Section IV

GLUE AND HARDWARE

17. Gluing of wood.—*a. General.*—Glue is used almost entirely as a means of joining wood in aircraft construction. A part is considered to be glued satisfactorily where the strength of the joint is approximately equal to the strength of the wood. A strong joint is characterized by complete contact of glue and wood surfaces over the entire joint area, with a continuous film of glue between the wood layers, unbroken by air bubbles or foreign particles. The details of the gluing operation control the result.

b. Moisture content.—The moisture content of wood at the time of gluing has much to do with the final strength of joints, development of checks in the wood, and warping of the glued members. The Army Air Forces require that the moisture content of all wood at the time of gluing be between 8 and 12 percent. In general, the higher the moisture content (up to 12 percent) the better the bond. Low moisture content of the wood will not allow the glue to wet the surface adequately and will sometimes cause starved joints. Gluing adds to the moisture content of the wood. The thickness of wood, the number of plies, the density of wood, the glue mixture, and the quantity of glue spread, all affect the increase in moisture content. The moisture added in gluing should be allowed to dry out or to distribute itself thoroughly in the wood before any machining or finishing is done. The aim should be to have the moisture content finally become that which the glued member will have in service. This is done in order to insure the full strength of the joint and to avoid subsequent warping of the glued member.

c. Preparation of lumber for gluing.—Lumber for gluing preferably should be machined just before gluing. The surfaces should be smooth and true, and plies or laminations for built-up work should be uniform in thickness. Hand surfacing is likely to produce local irregularities and uneven thickness in stock, and causes unequal pressure on joints. Scratching, tooth planing, or sanding the surfaces to be glued is unnecessary and frequently is a distinct disadvantage. The wood must be clean and free from varnish, shellac, lacquer, enamel, dope, or paint.

d. Proper gluing conditions.—The most important conditions involved in the production of strong joints are a sufficient spread of the glue on the wood surfaces and a correct balance between the consistency of the glue at the time of pressing and the amount of pressure used. Good joints may be made by coating either one or both contact faces. Excess glue that squeezes out after applying pressure should be scraped or wiped off.

e. Application of pressure.—Where relatively thin pieces are being glued, blocks which are true and uniform in dimension should be used between the clamp or press and the layers being glued. This is done in order to distribute the load from the point of contact to other parts not directly under the load, and to prevent clamps from crushing the wood. Unequal pressure on joints is also due to deflection and other imperfections in clamps or other pressing equipment. The initial pressure applied to glue joints tends to decrease as the glue squeezes out from between the wood layers or distributes itself in the joint. The clamps or other devices should be kept closely adjusted for a short time after the initial application of the pressure in order to insure that the correct amount of pressure is maintained. The hand devices commonly used in applying pressure to glue joints are shown in figure 40. A light pressure should be used with a thin glue, a heavy pressure with a thick glue, and corresponding variations in pressure should be made with glues of intermediate consistencies.

f. Assembly time.—Pressure should be applied and contact made in the joint before the glue becomes too thick to flow. Glue which is spread on dry wood becomes thicker on standing. Where pieces of wood are coated with glue and exposed freely to the air (open assembly), a much more rapid thickening of the glue occurs than where the pieces are laid together as soon as the glue is spread (closed assembly). In some gluing operations, conditions permit only a short time for assembly, and under such conditions relatively thick glue must be used. In other operations the assembly time may vary from less than a minute to as much as 25 minutes, and the glue must remain at a satisfactory consistency during the entire period.

g. Sanitation.—The glue pot, brushes, etc., should be cleaned thoroughly with warm water. Boiling water should not be used as the high temperature will set the glue. All left-over glue should be discarded.

18. Kinds of glue.—*a.* The developments in the field of adhesives is an important factor contributing to the revival of wood aircraft construction. Synthetic resin glues and casein glues are most important for aircraft. Blood albumen glues were formerly of importance in producing water-resistant plywood but they have been

displaced for bonding aircraft plywood by synthetic resin glues. In the fabrication of parts (ribs, spars, etc.), and in the assembly of the finished aircraft, casein and resin glues are used. Marine glues are used in wooden floats and hull construction but not for making joints where high strength is required.

b. Casein glue and synthetic resin glue which meet aircraft requirements have high strength qualities when dry; the strength of casein glue when wet (after soaking in water for 48 hours) may have 25 to 50 percent of its dry strength, whereas synthetic resin glue under such condition retains almost its full strength. With respect to durability in 100 percent humidity or prolonged soaking in water, casein glue eventually deteriorates, whereas synthetic resin glue has high durability if the resin is unadulterated.

c. The tendency of synthetic resin glue to foam is slight. The tendency of casein glue to foam is slight if not mixed too rapidly.

d. Casein glue has a pronounced tendency to stain certain woods. Synthetic resin glue produces no staining effect, but the glue may penetrate through thin or porous veneers.

e. The dulling effect of casein glue on tools is moderate to pronounced, and is moderate for synthetic resin glue.

19. Casein glue.—*a.* Casein glue is a mixture of casein (made from milk) and other materials (usually lime and one or more sodium salts), combined in such proportions as to dissolve the casein and to produce a mixture of satisfactory properties.

b. There may be some variation in the exact proportions of glue and water that must be used for each lot of glue, which usually is given in printed instructions placed by the manufacturer on each container. In the absence of definite instructions, the proportions of one part of glue and two parts of cold water, by weight, should be used. If this mixture should be too thick or too thin, this proportion may be changed only during the mixing. The proportions of glue and cold water must be weighed, not measured by volume, in order to obtain the same mixture each time. A pair of balances or small capacity scales should be used to insure that the weighing device is sufficiently sensitive.

c. For small quantities of glue, the mixing may be done by hand. For larger quantities, a dough type glue mixer, a drill press, or similar power device with a beater of wire or wood to do the stirring, may also be used, if a low spindle speed is maintained (approximately 120 rpm). The powdered glue is added to the water by sprinkling or sifting in slowly in order to prevent the formation of lumps. Water should never be added to the glue. The mixture must be agitated during the

entire time the dry glue is being added to the water. After the dry glue has all been added, the paddle speed is decreased to approximately 60 rpm and the stirring continued until the granular casein particles have gone into solution, producing a smooth, creamy paste. This usually requires from 20 to 30 minutes. With certain glues, the mixture must be allowed to stand a specified length of time after the preliminary mixing, as contained in the manufacturer's directions. Too rapid stirring introduces an excessive amount of air into the mixture and seriously affects its adhesive properties. In the event a batch contains lumps at the end of the mixing, it should not be used. Attempts to beat out lumps are inadvisable because a foamy glue will usually result. Containers of tin, galvanized iron, porcelain, or paper may be used for holding this glue. Containers of brass, copper, or aluminum should not be used because the alkali in the mixture will attack the metals.

d. The glue should preferably be applied with a mechanical spreader, but may be applied with a stiff brush or scraper. When a brush is used, care should be exercised to avoid the inclusion of broken or loose bristles in the glue. The glue should not be spread thin or brushed out in thin layers. A spread of approximately 1½ ounces of wet glue per square foot of single glue line is satisfactory. When practicable, glue should be applied to both surfaces. Clamps should ordinarily be applied immediately after the glue is spread, but a period of 10 to 15 minutes may safely elapse after the glue has been spread before applying pressure to the parts. Periods in excess of 20 minutes should be avoided. The useful life of mixed casein glue is 4 to 8 hours. The glue will eventually become so thick that it cannot be used; when this occurs or when the glue is older than 8 hours, it must be discarded. Once the glue has been mixed to the proper consistency, an additional amount of water is never added for the purpose of thinning out the glue. Satisfactory joints are obtained when the glue is applied at ordinary room temperatures. For softwoods, such as spruce, a pressure of 125 to 150 pounds per square inch, and for hardwoods, such as ash, a pressure of 150 to 200 pounds per square inch should be used with relatively thick glue.

e. Pressing time for casein glue should, in general, be 7 hours or more. Where it is convenient to do so, it is better to maintain pressure from one day to the next. A longer length of time before removing the clamp is preferred and may be required where joints cover an extended surface or where it is necessary to use large quantities of glue in proportion to the volume of the wood in the member. Hand work on glued parts may be done as soon as removed from the clamps. No glued part should be machined within 12 hours after the glue has been applied.

f. Casein should be stored in a dry place, in the original containers.

20. Synthetic resin glue.—*a.* Of the many types of synthetic resins, two have found wide use as woodworking adhesives. These are the products formed by the reaction of an aldehyde (usually formaldehyde) and phenol, and of urea with formaldehyde. In preparing these products for use as adhesives, the reaction between the chemicals is stopped at an intermediate stage in which the product may be applied, the parts assembled, and the reaction completed under simultaneous application of heat and pressure (hot pressing). Some are applied in the form of a film (thin paper impregnated with phenol formaldehyde resin), some in aqueous suspensions or solutions, and others in alcohol solution. Some are available that can be applied and pressed at room temperatures (cold pressing); these depend upon the addition of a catalyst or hardener, to cause the condensation reaction to proceed at room temperatures. The use of the synthetic resin adhesives for maintenance and repair is generally limited to room temperature setting glues (cold pressing). Without special devices and methods for applying heat and pressure to the glued joints, no effective use can be made of the high temperature setting glues (hot pressing).

b. Mixing directions supplied by the manufacturer should be followed carefully. The quantity of the various components should be determined by weight, particularly so because some of the components may be added in comparatively small quantities. The resin glues in film form are ready for use when received. Mixtures of cold setting resin glue are available in liquid or powder form. One type of powder form has a catalyst incorporated in it; the mixture is made ready for use by the addition of water. Other mixtures, in liquid or powder form, require the addition of a catalyst. The catalyst should be added to the glue during or after mixing with water, and should not be applied separately to the work. Dough type mixers are satisfactory for mixing resin glue. Particular care must be exercised to insure that all traces of alkali (such as remnants of casein glue from previous mixtures) are removed, because even minor amounts or traces of alkaline materials seriously affect the working properties of synthetic resin glue.

c. The working life of cold press synthetic resin glue is usually between 4 and 5 hours at 70° F. (21.1° C.).

(1) Cold press synthetic resin glue changes consistency relatively slowly, and permits considerable variations in assembly periods. It seems advisable, however, to avoid the very short assembly periods for cold press resin glue, or else reduce the pressure somewhat.

(2) The duration of pressure for cold press synthetic resin glue is, in general, the same as for casein glue. It is recommended that the

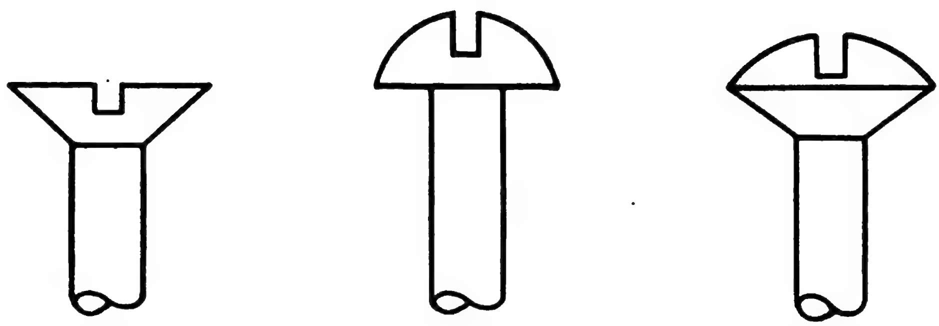
pressures stated for casein glue with hardwoods and softwoods be used for synthetic resin glue, but the spread of glue may be slightly reduced.

(3) An increase of temperature would be the most effective way to increase the rate of setting. As they are formulated at present, the cold press synthetic resin glues should not be used where the temperature of the gluing room and wood are below 70° F.

d. (1) The powder forms of glue should be stable for a period of at least 1 year, and the liquid form for a period of at least 2 months, when stored in an airtight container at a temperature not exceeding 80° F.

(2) The powder form of glue, with separate catalyst, should be ordered when maximum stability in storage is desired.

21. Screws.—*a.* Wood screws are commonly used for fastening wooden parts together and for fastening metal parts to wood. The use of wood screws in the primary structure of the airplane is prohibited except in cases when the suitability of the particular application is specified. The most common wood screws are those made of steel or brass, with flat, round, or oval heads (fig. 20). Wood screws



① Flat. ② Round. ③ Oval.

FIGURE 20.—Screw head shapes.

of aluminum alloy with either flat or round heads are also available. They are ordinarily used to attach aluminum alloy to wood where the use of a steel or brass screw would have a corrosive effect, as between two dissimilar metals, and also where lightness or nonmagnetic properties are required. The heads of the wood screws are made with either straight slots or cross slots. The cross slot type of screw head requires a special screw driver (fig. 41) for driving.

b. Wood screws are identified as follows:

(1) Material.

(2) Type of head.

(3) Diameter (at shank), designated by gage number.

(4) Length, in inches.

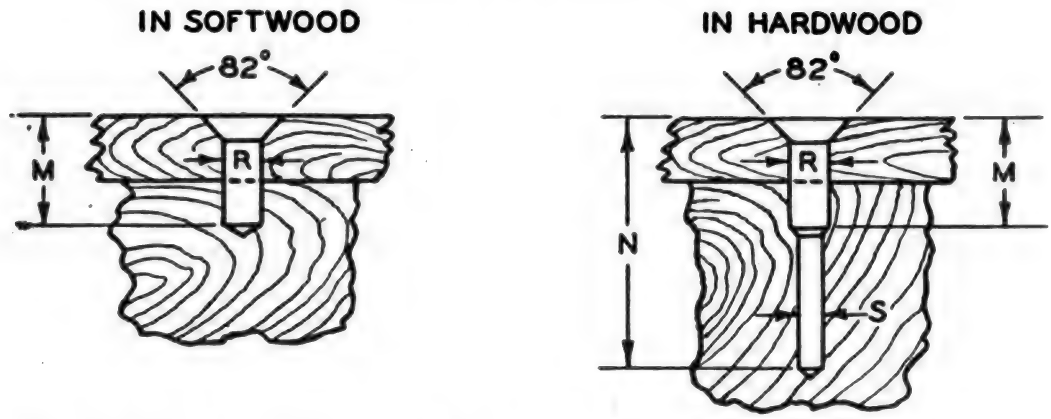
For example, a flathead wood screw would be designated in the stock list as "Screw—wood, steel, F. H., No. 4 x 3/4 inch." Table I gives gage numbers and corresponding diameters of representative wood screws. Length of screws vary for each gage number.

c. To fasten two pieces of hardwood stock with screws, two sizes of holes must be drilled: one just large enough through the first piece, and if necessary, into the second piece, to accommodate the shank of the screw without binding; the other just large enough into the second piece to provide clearance for the core (diameter at root of threads) of the screw, thus leaving enough wood to permit the threads of the screw to be anchored in the sides of the hole. The combined depth of the two holes should be slightly less than the over-all length of the screw. For softwood, only a hole large enough to accommodate the screw shank need be drilled. Table I gives drill sizes and depth of holes for various sizes of screws.

TABLE I.—*Drilling for wood screws*

Values for "M" apply only when "M" is greater than or equal to thickness of top piece.

Body of screw		Drill sizes				Length of screw	Depth of drill for—	
Gage No.	Diameter	No.	Diameter	No.	Diameter		Body	Threads
D		R		S		L	M	N
0	0.060	53	0.059	57	0.045	1/4	3/32	3/16
1	.073	50	.070	54	.055	3/8	1/8	5/16
2	.086	44	.086	52	.063	1/2	3/16	7/16
3	.099	40	.098	49	.073	5/8	7/32	9/16
4	.112	35	.110	48	.076	3/4	9/32	11/16
5	.125	30	.128	44	.086	7/8	5/16	3/4
6	.138	28	.140	38	.101	1	3/8	7/8
7	.151	24	.152	33	.113	1 1/4	15/32	1 1/8
8	.164	19	.166	32	.116	1 1/2	5/8	1 3/8
9	.177	16	.177	30	.128	1 3/4	21/32	1 19/32
10	.190	12	.189	29	.136	2	3/4	1 13/16
12	.216	2	.221	25	.149	2 1/4	27/32	2 3/32
14	.242	D	.246	16	.177	2 1/2	15/16	2 5/16
16	.268	I	.272	7	.201	2 3/4	1	2 9/16
						3	1 1/8	2 13/16
						3 1/2	1 5/16	3 5/16



22. Nails.—*a.* Although nails are the most common fasteners used in woodwork, they have limited application in wood aircraft construction. Gluing is the most satisfactory method of securing wood joints; the use of nails, in addition to the glue, only adds weight, crushes the wood, and decreases the strength of the joint. Tests have demonstrated that the nails do not come into action until the glue has given away and that the reduction in strength caused by each nail is equivalent to that caused by a bored hole having the diameter and the length of the nail. Unless specified, the use of nails is restricted. They are, however, used as a means of holding in place glued parts, such as plywood covering, rib gussets, and corner blocks which are difficult to clamp. In some permissible cases where it is more convenient and the decrease in holding strength of the glue is not appreciably affected, the nails are left in.

b. Nails used in airplane construction are steel or brass, cement-coated, barbed, flathead nails, in sizes as shown in table II. Other nails used for general woodworking purposes include the finishing nail, common brad, common nail, box nail, etc.

TABLE II.—*Cement-coated flathead nails*

Length (inches)	Gage No. and decimal equivalent			
	No. 20 (0.035 in.)	No. 18 (0.047 in.)	No. 16 (0.062 in.)	No. 14 (0.080 in.)
¼	X			
⅜	X	X		
½	X	X	X	
⅝	X	X	X	
¾	[1] X	X	X	X
1		X	X	X
1¼			X	X
1½				X

[1] Steel only.

c. The sizes of the common nails, finishing nails, and box nails are designated by "penny" sizes, the symbol for which is "d." Thus, the sizes of these nails are referred to as 2d, 4d, 10d, etc. The term originally was based upon the cost of various size nails by weight per thousand. Common brads are designated by length and diameter.

SECTION V

HAND TOOLS

23. General.—Tools are designed for specific purposes and should be used as intended, and be properly maintained if they are to give good service. Woodworking tools, especially the edge of cutting tools, require particular attention and careful handling to maintain them sharp and in good condition. The use of dull or damaged tools is poor practice; inaccuracy, damage to work, or injury to person may result. Although a wide variety of tools is available, only those most commonly used in the woodshop are described in the succeeding paragraphs.

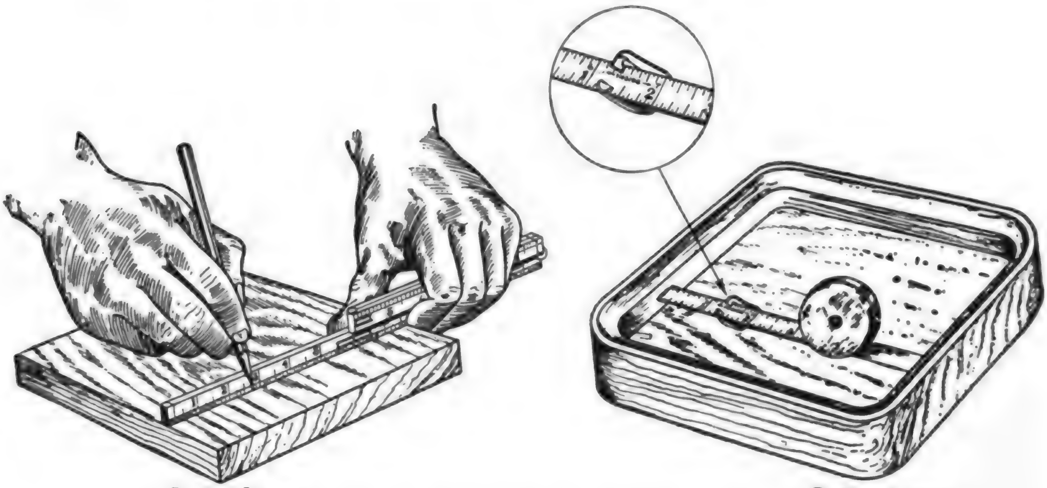
24. Rules and tapes.—*a.* Rules and tapes are graduated measuring devices. The types commonly used for woodworking include the straight rule (1- or 2-foot), zigzag rule (4- or 6-foot), folding rule (2-foot), steel tape rule (6-foot), and steel tape (50-foot).

(1) The straight rule is used mostly for bench work.

(2) The zigzag rule, folding rule, and steel tape rule may be carried about handily, and are used for miscellaneous measurement.

(3) The steel tape is used for measuring long lengths.

b. Proper use of measuring devices is essential in accurate lay-out. Lay the rule on edge (see fig. 21①) when marking off distances shorter than the rule. This brings the rule graduations directly on the surface of the stock, minimizing the possibility of error in marking. Use a sharp pointed knife, sharp pencil, or scratch awl for making the mark. Avoid heavy lines, since the thickness of a line may be the difference between a good or poor fit. Check all measurements carefully. The steel tape rule is equipped with a device for measuring inside dimensions. Adjust the rule (see fig. 21②) and read the indicator along the top scale designated "inside." Use a long rule for marking of long lengths. Spacing off a long length with a short rule may result in inaccuracy, as a fraction of an inch may be either gained or lost each time the rule is moved.

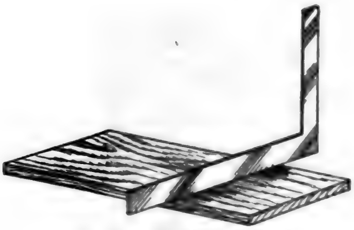


① Folding. ② Steel tape.

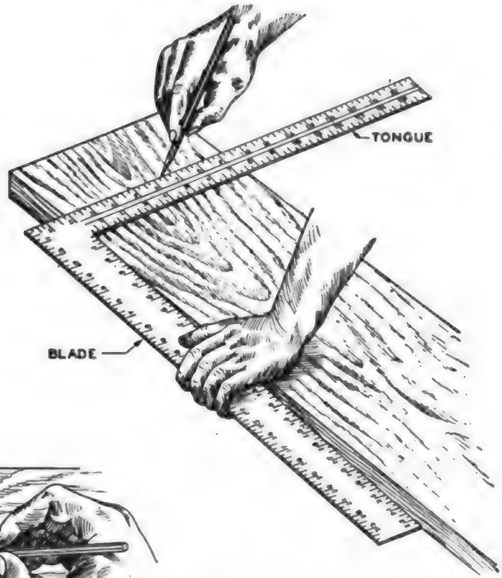
FIGURE 21.—Folding rule and steel tape rule.

25. Squares.—*a.* The framing square (fig. 22) is used for level testing, testing squareness of large surfaces and assembled pieces, and for marking stock preparatory to cutting or assembling. It is also frequently used to lay out various angles other than right angles. A 45° angle is obtained as shown, using equal graduations on the tongue and blade. Other angles may be obtained in a similar manner using different combinations of graduations.

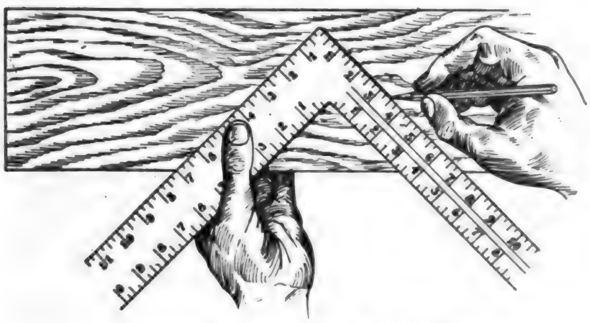
b. The try square (fig. 23) is used for laying out and testing square cuts, testing squareness of small assemblies, and for general truing operations. The blade is centered in the width of the handle of the try square, thus permitting the blade to lie flat on the work, for accurate marking.



① Testing a surface.

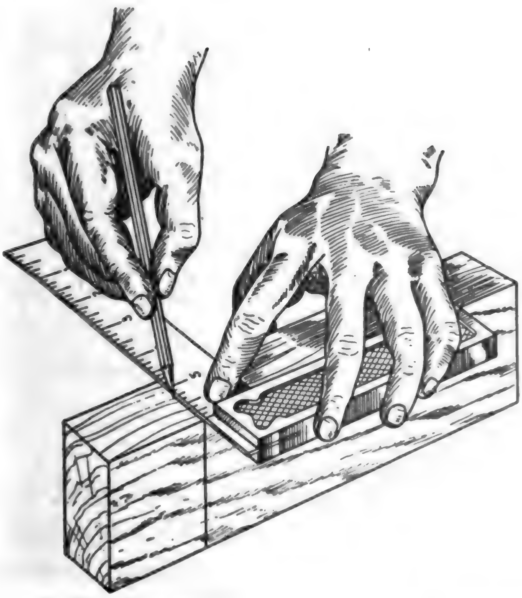


② Marking stock squarely.

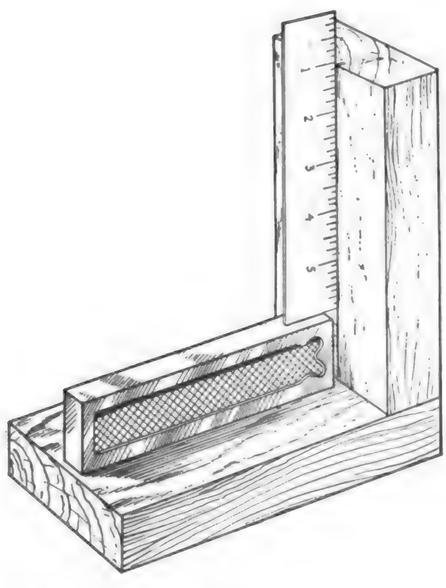


③ Laying out a 45° angle.

FIGURE 22.—Application of framing square.



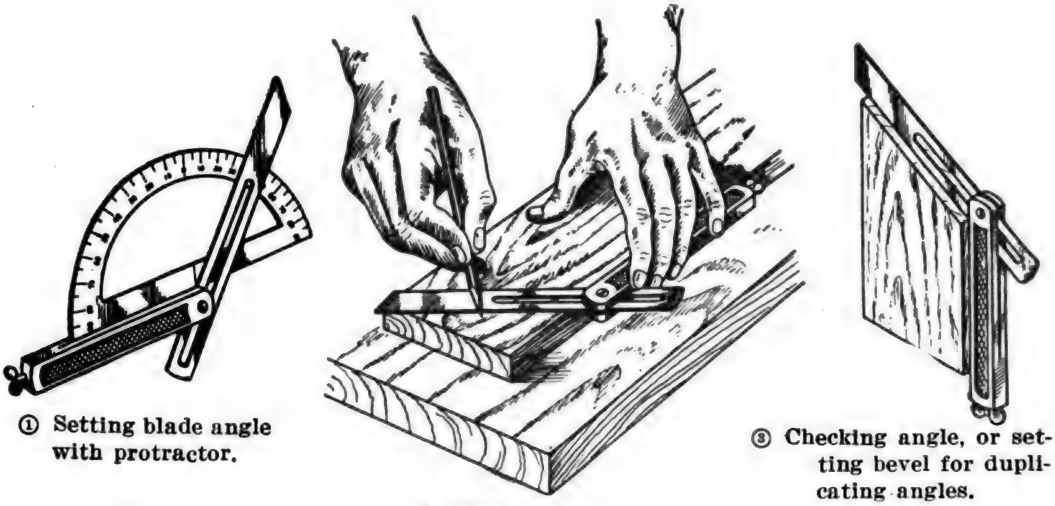
① Marking stock.



② Testing squareness.

FIGURE 23.—Try square.

c. The sliding T-bevel (fig. 24) is used for laying out and checking angles. The bevel is used in the manner of a try square after the blade is set to the desired angle. The blade angle setting may be obtained from a protractor, a given angular cut, or a framing square.



① Setting blade angle with protractor.

② Marking angle.

③ Checking angle, or setting bevel for duplicating angles.

FIGURE 24.—Sliding T-bevel.

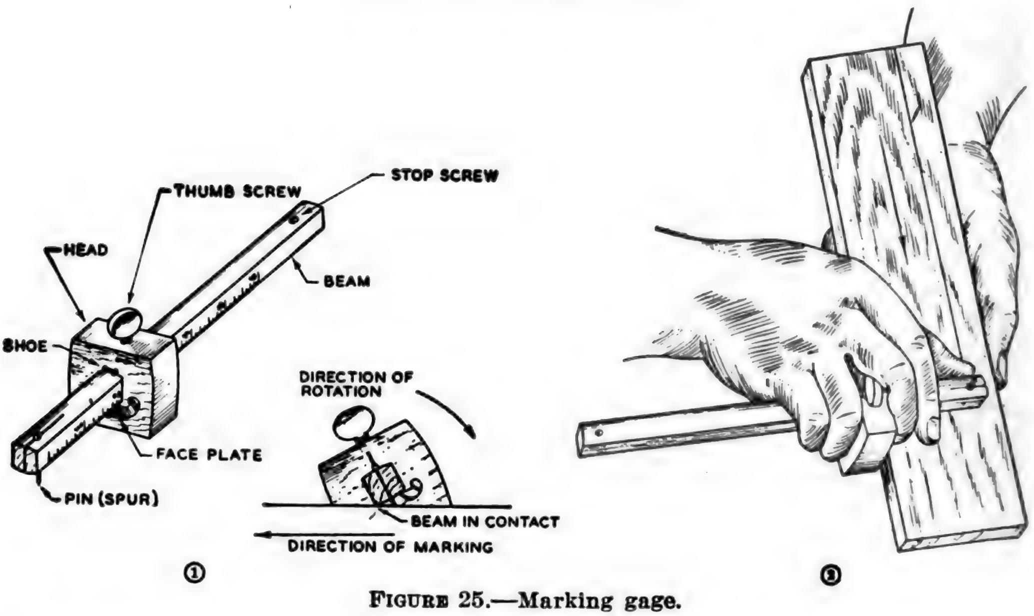


FIGURE 25.—Marking gage.

26. Marking gage.—*a.* The marking gage (fig. 25) is used for marking lines parallel to a surface of wood stock. The mark is indented in the wood by a metal point or spur located at one end of the gage.

b. In using the gage, the important consideration is to keep the head flush against the board to enable the point to travel in a straight

line. Grasp it firmly, and rotate the beam until the spur lightly marks the wood; the gage is then pushed along the stock to make the mark. A light mark is more accurate. If the point digs too deeply, it will tend to follow the grain and an imperfect line will result. It is necessary to grip the gage correctly, as shown, and apply the force directly behind the point to keep the point moving in a straight line. Do not use the gage for marking across grain or for laying out chamfers. The point tears the fibers when marking across grain, and in chamfering may leave a mark too deep to remove without increasing the size of the chamfer.

27. Dividers.—The dividers (fig. 26①) are used for laying out circles and parts of circles. They are also used to divide spaces, to step off distances, and to transfer dimensions from a rule. Some dividers are equipped with a removable leg to permit attachment of a pencil in place of the steel point; the dividers may then be used as a compass.

28. Trammel.—*a.* A trammel (fig. 26②) consists of a wooden bar to which trammel points are attached; the assembly is used in the manner of dividers or compasses. The points may be fixed in any position on the bar by means of thumbscrews. A trammel is used for scribing arcs and circles of large radius beyond the capacity of dividers. It is also used for laying out and checking measurements.

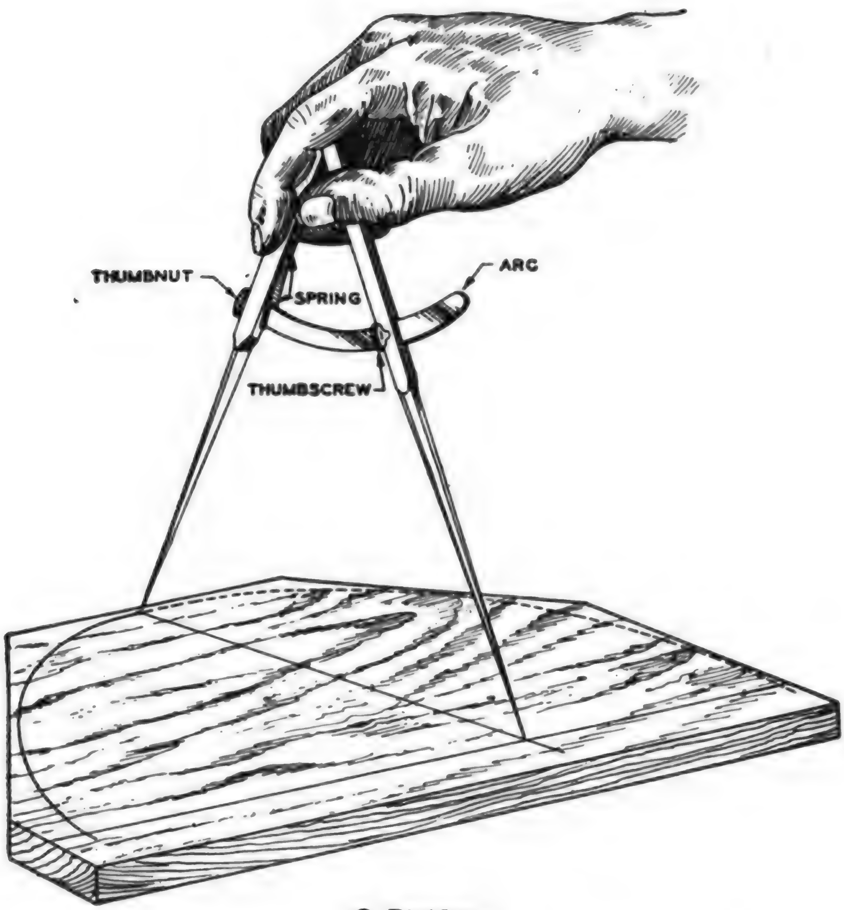
b. In using a trammel, care must be exercised to avoid inaccuracy, especially when the points are spaced wide apart on the bar. A slight pressure on the bar will bend it, causing a variation in the distance between the points. For this reason, always hold the trammel at the points during use. Never force the trammel, especially when checking distances or squaring frames; allow the points to rest gently on the work.

29. Scratch awl.—*a.* The scratch awl (fig. 27) is a pointed steel instrument used for marking lay-outs and locating points for nails, screws, hole centers, etc.

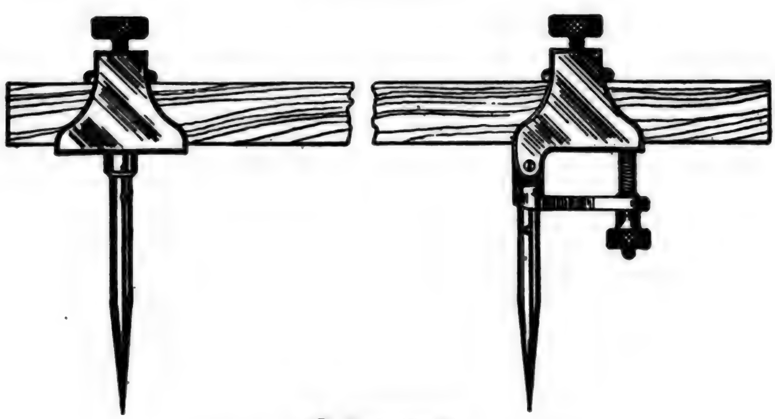
b. For marking lines, use the awl as a pencil, scratching the wood lightly. In locating holes for screws, etc., press the awl into the wood to provide a guide mark.

30. Brace.—*a.* The brace (fig. 28①) is used to hold various wood bits, screw driver bits, and similar devices. Size is designated in terms of sweep, which refers to the diameter of the circle made by the handle; 8- and 10-inch sizes are commonly used. The larger size gives more leverage for turning large bits or tightening screws. In most types, a ratchet arrangement is incorporated between the handle

and chuck to allow a partial revolution of the brace in restricted quarters. The brace is usually equipped with the type chuck shown, for bits having a tapered square tang.



① Dividers.



② Trammel.

FIGURE 26.—Dividers and trammel.

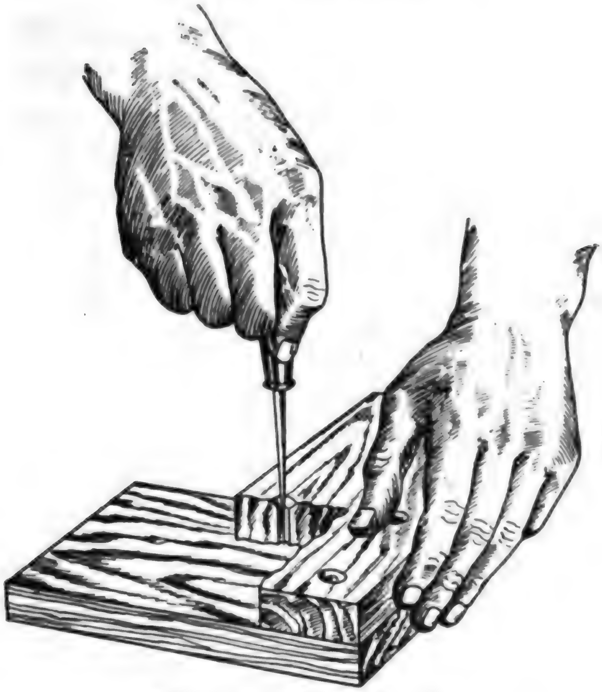


FIGURE 27.—Scratch awl.

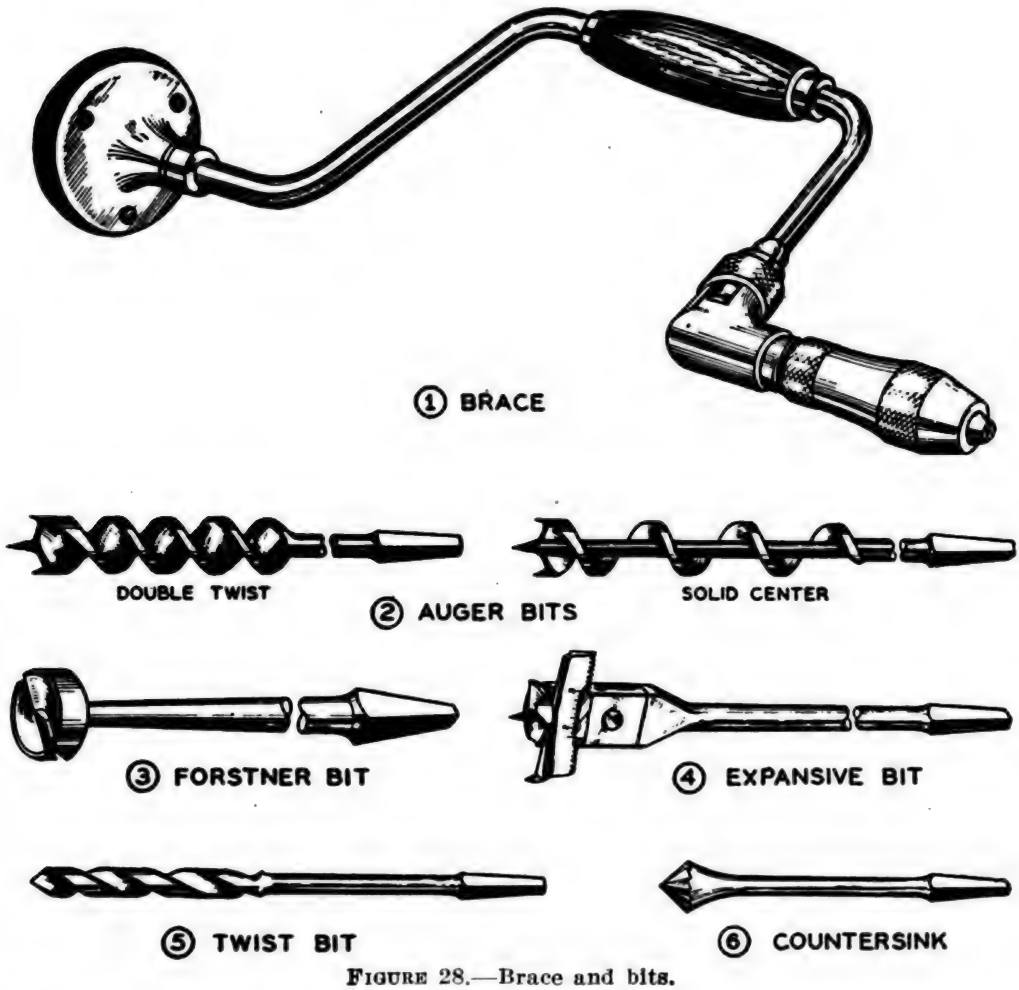


FIGURE 28.—Brace and bits.

b. To secure a bit properly in the chuck, open the jaws wide and insert the bit so the corners of the tang are carefully seated in the V-grooves. Tighten the jaws around the tang, exercising care that there is no "play" or looseness which might cause the bit to wobble or run out of true. Whenever possible, operate the brace in such a position that it can be steadied against the body (stomach or chest). In restricted quarters, set the ratchet by turning the knurled cam ring. Turning the cam ring permits the handle to rotate independently of the chuck, in one direction. When tightening screws, use the ratchet feature to locate the handle of the brace in a position which will afford the most advantageous leverage.

31. Wood bits.—*a.* Wood bits are used to bore and shape holes in wood to accommodate bolts, screws, nails, dowels, etc. The types commonly used are as follows:

(1) The auger bit (fig. 28②) is used for most boring operations where a hole 1/4 inch or larger is required. Size is indicated by a number stamped in the tang, and refers to the diameter of the bit in sixteenths of an inch (a No. 9 bit, for example, will bore a hole 9/16 inch in diameter). Sizes range by sixteenths.

(2) The Forstner bit (fig. 28③) is used to advantage in boring holes in end grain, thin wood, or near the end of a board where an auger bit might split the wood. It may also be used to bore a hole almost through a board, since it has no point or long spurs to break through and mar the opposite surface. Sizes range from No. 4 (1/4 inch) and larger, the number indicating the size in sixteenths.

(3) The expansive bit (fig. 28④) is designed for boring large size holes. It is frequently used in place of the larger size auger bits. The bit shown is supplied with two adjustable cutters and will bore holes from 7/8 inch to 3 inches in diameter.

(4) The twist bit (fig. 28⑤) is used for boring small holes. Sizes range from No. 2 (1/16 inch) and larger, the number indicating the size in thirty-seconds.

(5) The countersink bit (fig. 28⑥) is used to shape holes for recessing flathead screws. Common sizes are 1/2, 5/8, and 3/4 inches.

b. Boring and countersinking may be accomplished easily and successfully if a few precautions are exercised.

(1) To bore with an auger bit, first locate the hole by careful measurement. Mark the location with a scratch awl or center punch. Place the point of the bit in the mark and hold the brace so that the bit maintains the proper angle with respect to the work. Test the angle with a try square, squared end of a board, or a sliding T-bevel. Steady the brace and rotate the handle slowly. It is not

necessary to apply excessive pressure to the brace; the screw point of the bit pulls it into the wood. If the hole is to extend through the board, stop boring as soon as the tip breaks through (fig. 29①) and finish boring from the opposite side. When boring a number of holes to a given depth, attach a bit depth gage (bit stop) as shown in figure 29②, so that the bit will stop at the required depth. When removing a bit from a relatively deep hole, turn the brace to the left a few turns to release the screw point, pull on the brace handle, and rotate it to the right until the bit is free. Turning the bit to

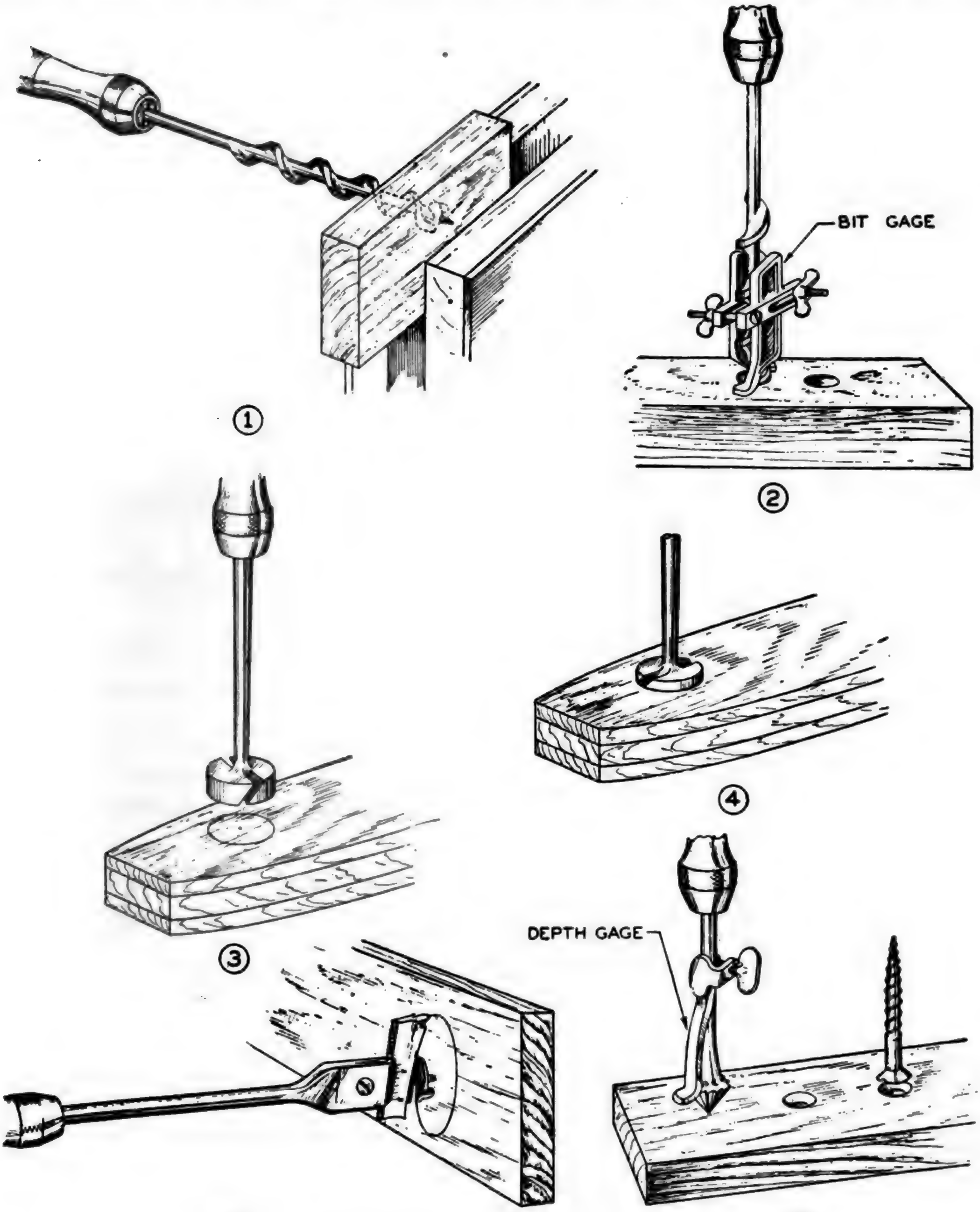


FIGURE 29.—Use of wood bits.

the right removes the chips and clears the way for easy removal of the bit. After the screw point is free, continued rotation of the bit to the left only tends to pack the chips in the hole, jamming the bit and sometimes preventing its removal.

(2) The Forstner bit has no center point and must be pressed or tapped into the wood to start it. First, locate the center of the hole and mark it with a scratch awl. With a divider, scribe a circle in the wood (fig. 29③) the size of the hole desired. Place the rim (cutting edge) of the bit on the circle (fig. 29④) and press it into the wood. Apply pressure to the brace and bore the hole.

(3) It is preferable to use an expansive bit for boring holes larger than 1 inch. To adjust the bit, loosen the plate screw and slide the cutter to the desired position as indicated on the scale. Test the setting of the cutter by running the bit into a piece of scrap stock until the spur cuts a circle (fig. 29⑤). Measure the circle to check the adjustment of the cutter. If the hole is to go through the board, clamp a piece of scrap stock to the back of the work and continue boring through the board into the scrap stock. This produces a clean-cut hole and prevents splintering the face of the work when the bit comes through. Use a brace with a large sweep in order to obtain the necessary leverage, especially when boring extremely large holes.

(4) During countersinking, the depth and diameter of the chamfer may be checked with the head of the screw to be used in the hole. Use a depth gage (fig. 29⑥) to achieve speed and uniformity when countersinking a number of holes to the same depth.

32. Drills.—Holes smaller than ¼ inch are usually drilled with an automatic drill or small hand drill. These drills are faster and less cumbersome than the brace. Also, there is less danger of breaking small drill bits with such drill.

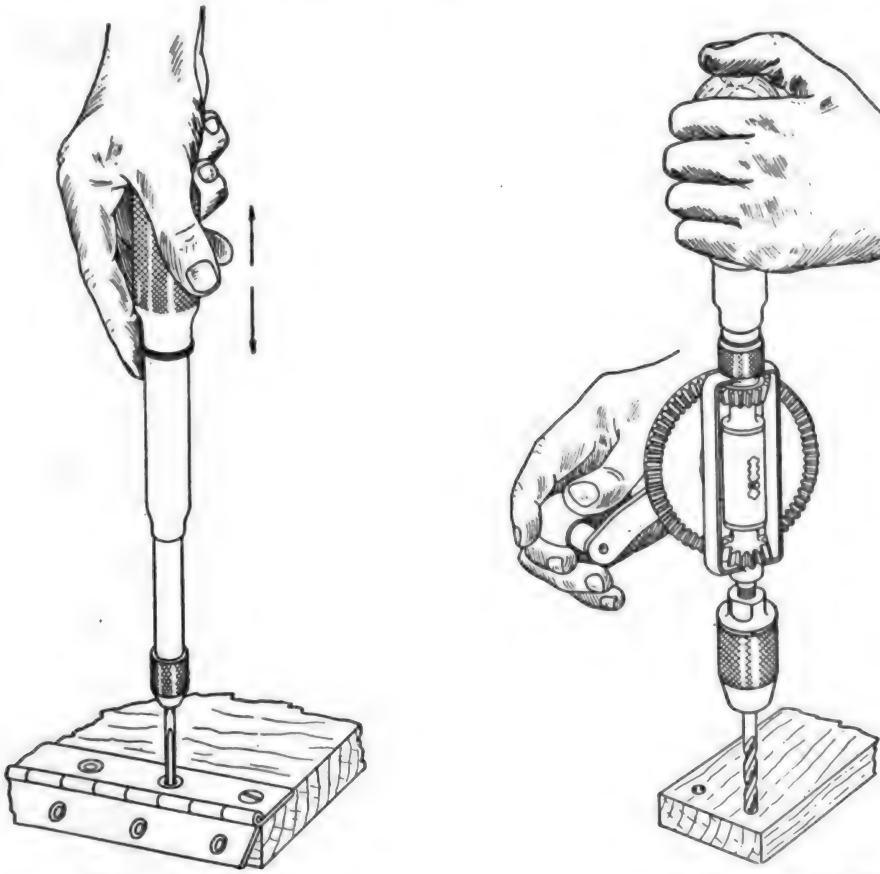
a. Automatic.—(1) The automatic drill (fig. 30①) is equipped with special light drill points ranging in size from 1/16 to 11/64 inch by sixty-fourths and carried in the handle.

(2) The drill is operated by a push-pull action on the handle. It is usually held in one hand, leaving the other free to steady the work or hold parts together while drilling.

b. Hand.—(1) The small hand drill (fig. 30②) is equipped with a three-jaw chuck to accommodate small size round shank twist drills.

(2) For most applications, hold the drill as shown. Where pressure is required on the drill, brace the top handle against the chest. Hold the drill steady while drilling; wobbling or change of direction may break the bit. Avoid excessive pressure on the drill because

small size drill bits may bend and break. After the hole is completed, withdraw the drill, turning in the same direction as when drilling, while pulling on the handle; this clears the hole. For drilling through, it is best to clamp a piece of scrap stock on the back of the wood to avoid splintering.



① Automatic drill. ② Small hand drill.

FIGURE 30.—Automatic and hand drills.

33. Wood chisels and gouges.—*a.* (1) Wood chisels and gouges are used for various cutting and paring operations involved in chamfering, mortising, grooving, recessing, etc. The socket type chisel (fig. 31①), referred to as socket firmer chisel, is designed to withstand the blows of a mallet where one is required to drive the chisel into the wood. The tang type chisel (fig. 31②) has a ferruled handle which is not as strong as the socket type. It is used chiefly for paring and trimming operations where a mallet is not required. The gouge is simply a chisel with a rounded blade, beveled either on the inside or outside (fig. 31③ and ④) of the curve. The degree of curvature or sweep of the blade may be flat, medium, or regular. The outside bevel gouge is most generally used. It may be held at an angle with the work, and is used for cutting rounded grooves,

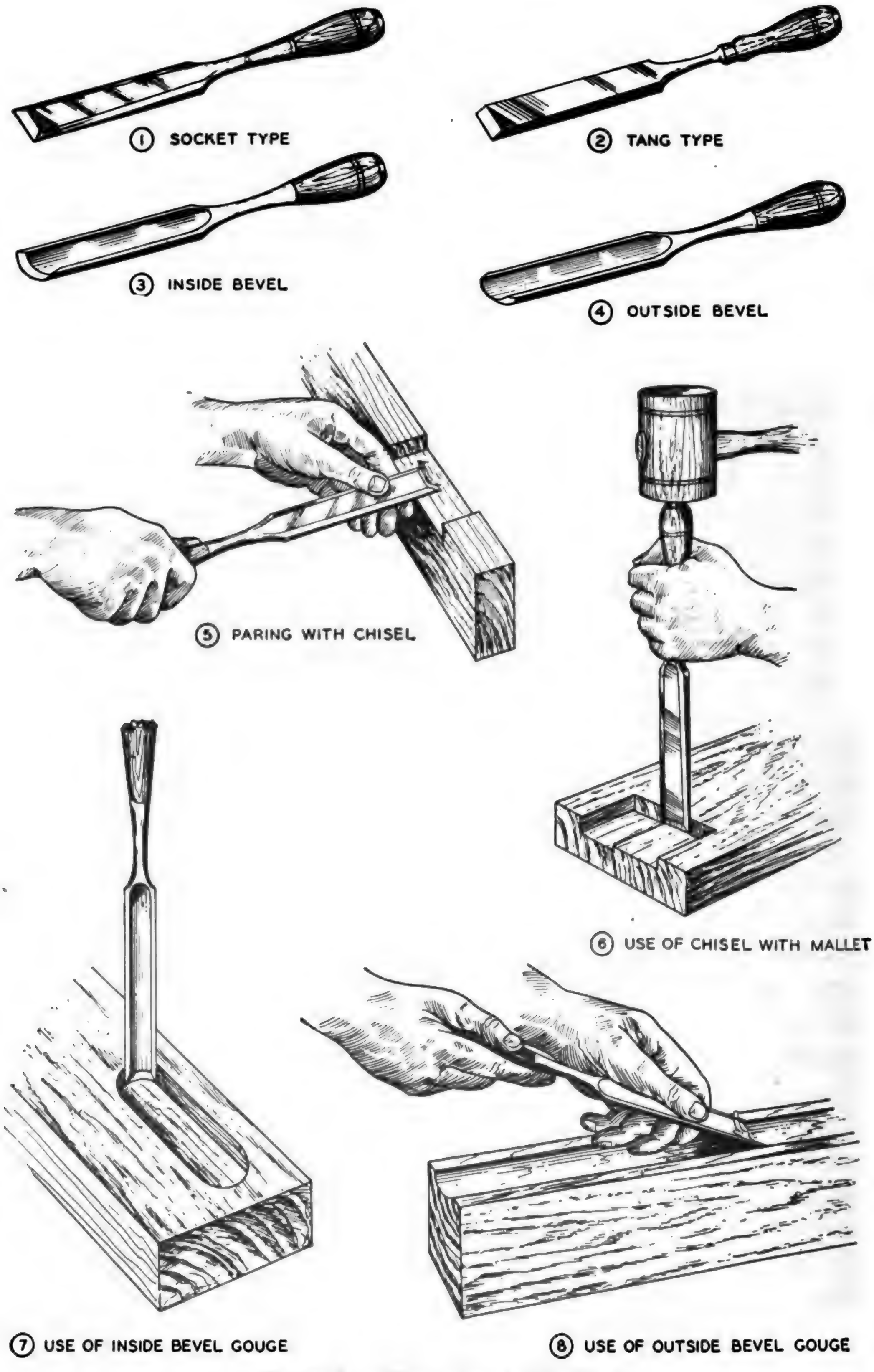


FIGURE 31.—Wood chisels and gouges.

recesses, etc. The inside bevel gouge is used for cutting holes with straight sides or for light paring in making concave outlines.

(2) Sizes of chisels and gouges are determined by the distance across the blade, and generally range from 1/8 inch to 2 inches.

b. Most of the work with the chisel or gouge may be accomplished by hand without the aid of a mallet. However, certain operations, such as cutting across grain, require the use of a mallet to drive the tool. Cuts should be made with the grain or across the grain; cutting against the grain should be avoided if possible, as the wood is likely to split beyond the desired point. Operations with the chisel and gouge may be easily performed if the tools are sharp and properly controlled.

(1) When cutting across grain on narrow stock, hold the chisel as shown in figure 31⑤, with bevel up. The thumb and forefinger of the left hand control the chisel, acting as a brake to prevent it from sliding the full way across and splintering out the opposite side of the work. Cut halfway from both edges, removing the center wood last. Hold the chisel perfectly flat when finishing to obtain a flat surface. Sliding the chisel sideways as it moves across the stock produces a smoother cut. If, on wide stock, the handle prevents the blade from lying flat, turn the bevel down and hold the chisel in the same manner. When paring along the grain or shaving end grain, the same procedure is used as for cross grain. When removing considerable stock or when the wood is hard and tough, the use of a mallet is advantageous (fig. 31⑥).

(2) The gouge is used in much the same manner as the chisel. For heavy gouging or cutting across grain (fig. 31⑦), fasten the work securely in a vise, or with clamps, and use a mallet to drive the gouge. For light paring, use only the hands, holding the gouge as shown in figure 31⑧. Push the gouge with the right hand, slightly rotating the cutting edge sidewise to produce a slicing action. Guide and control the gouge with the left hand to prevent it from slipping.

34. Drawknife.—*a.* The drawknife (fig. 32) is used to remove surplus stock which cannot conveniently be removed by planing, sawing, or other means. Size refers to the length of blade, the 10-inch blade being most commonly used.

b. Fasten the stock securely in a vise or with clamps. Work with the bevel down and in such a direction that the wood will split away from the outline. Regulate the depth of cut by tilting the blade toward or away from the work and draw it laterally across the work to produce a slicing action. When working close to the outline, take light cuts to prevent splitting or accidentally removing too much stock.

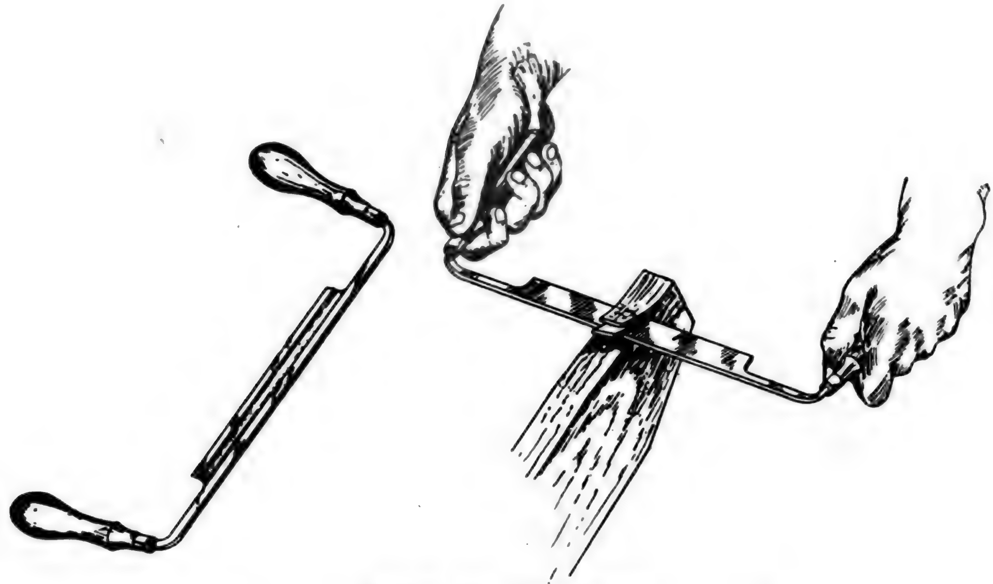


FIGURE 32.—Drawknife.

35. Plane.—*a.* The hand plane is used for smoothing, truing, and for removing excess stock. The common types are shown in figure 33.

(1) The smoothing plane (fig. 33②) ranges in length of bed from 6 to 10 inches. It is used for leveling and smoothing surfaces and for fine trimming.

(2) The jack plane (fig. 33③) is an all-purpose plane and is most generally used. It has a bed about 14 inches long with either a smooth or corrugated bottom. The jack plane may be used to do the work of the smoothing or jointing planes in many instances.

(3) The block plane (fig. 33④) is short, ranging in sizes from 4 to 8 inches in length of bed. The plane iron is set at a low angle, with the bevel up. It has no cap iron, being designed especially for cutting end grain. However, it is also used for miscellaneous light trimming operations.

(4) The jointer (fig. 33⑤) has an exceptionally long bed, 22 to 30 inches in length. It is used for jointing (truing) the edges of long stock in preparation for gluing. It is also used for leveling and smoothing large surfaces.

b. (1) Much the same procedure is followed in using either the jack, jointer, or smoothing plane. Proper adjustment is essential. Set the plane iron cap (shaving breaker) as indicated in figure 33①, and after the plane is assembled (fig. 33②), turn adjusting nut so that cutting edge of plane iron projects slightly beyond the bed. Sight along the bottom of the plane and regulate the lateral adjusting lever to bring the cutting edge parallel with the bed surface. Secure the work in a vise or on the bench and assume a firm, easy position

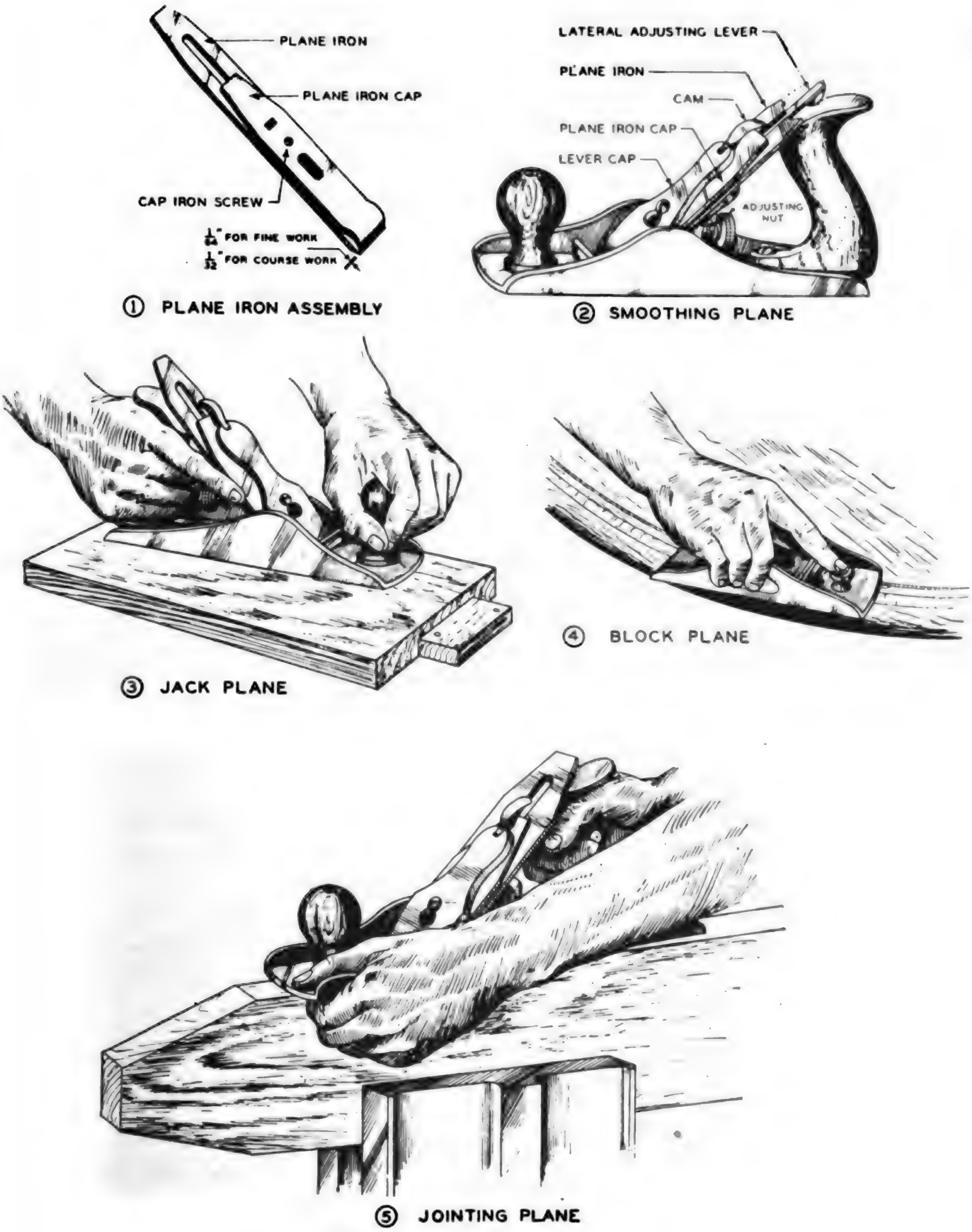


FIGURE 33.—Hand planes.

alongside the work, holding the plane in the hands (see fig. 33③). At the beginning of the stroke, apply a downward pressure to the knob of the plane; push the plane forward, shifting the pressure to the handle of the plane at the end of the stroke. Lift the plane as the cut is finished. Guide the plane carefully on an edge or on narrow stock (fig. 33⑤) to prevent it from wobbling and making an irregular cut. It is best to make one continuous cut across the work when possible. This leaves a smooth, even surface. When planing or smooth-

ing a wide, flat surface, make an angular sweep across the work with the grain (see fig. 33③). The sidewise movement of the plane produces a slicing action, making a smoother surface. When planing end grain, set the plane for a fine cut and take short strokes. Work from both edges toward the center to avoid splitting the edge. End grain may be planed without danger of splitting if sufficient excess stock remains to permit chamfering the farthest edge.

(2) The block plane is operated with one hand leaving the other free to hold or steady the work. Regulate the depth of cut by turning the adjusting screw. To adjust the plane iron laterally, loosen the lever cap screw slightly, then shift the iron right or left by tapping it lightly. Sight along the bottom of the plane to determine the proper setting, then tighten cap screw.

36. Spokeshave.—*a*. The spokeshave (fig. 34) is a form of plane. It has a short bottom, enabling it to follow curves readily. Several types are used, differing in the shape of the bottom. A straight bottom type is used for trimming curves having a long sweep. The convex bottom is used especially for shaping sharp concave curves. For rounding edges and shaping round stock, a concave bottom spokeshave is used.

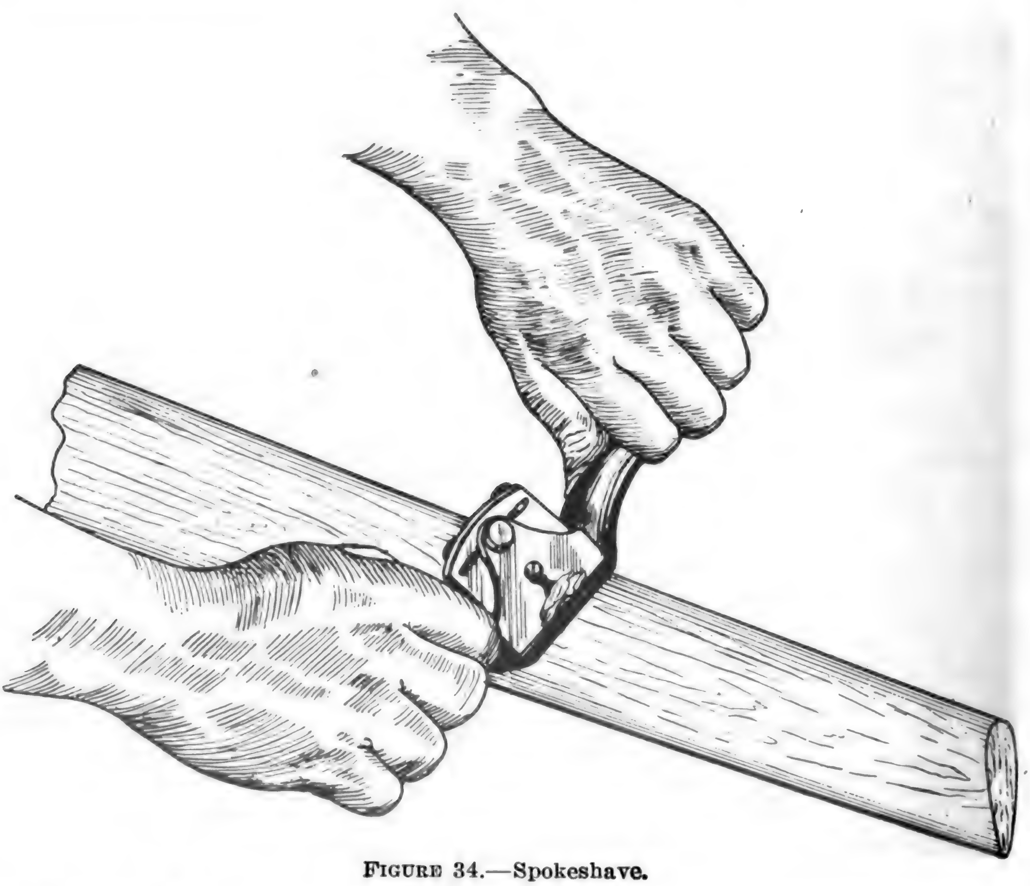
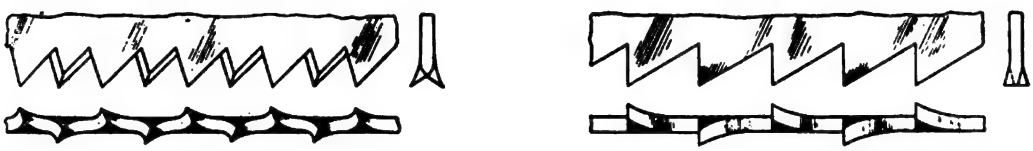


FIGURE 34.—Spokeshave.

b. The spokeshave is generally pushed, but in some instances a pulling stroke is used. Adjust the blade by turning the adjusting nuts until the blade projects evenly and cuts a thin shaving. Work with grain of the wood for smooth cutting.

37. Saws.—Hand saws are used for a variety of cutting operations. Those most commonly used are the crosscut, rip, back, dovetail, coping, and miter saws.

a. Crosscut.—(1) The crosscut saw is used for cutting across the grain of the wood, either straight across or diagonally. Sizes usually range from 20 to 26 inches in length and vary in number of teeth per inch. The 26-inch length with 8 or 10 teeth per inch is commonly used. The number of teeth per inch is stamped on the blade near the handle. Crosscut teeth (fig. 35①) are filed on an angle to produce knifelike edges which cut the fibers of the wood into small particles (sawdust). Alternate teeth are bent outward (set) in order to make a wider cut and to provide clearance for the blade of the saw. Some saws have a tapered blade, thinner at the back than at the teeth, to provide added clearance.



① Crosscut teeth. ② Ripsaw teeth.

FIGURE 35.—Hand saw tooth shapes.

(2) The stock is ordinarily supported in a vise. However, if the piece to be cut is large or long, support it on sawhorses or other device, a convenient height from the floor for kneeling on it to hold the work (fig. 36①). Assume a position to one side of the cut to permit free and easy movement of the arm. Avoid a cramped position, as this tends to bind the saw. Guide the saw with the thumb and start the cut on the waste side of the line. Make a few short, light strokes at first, holding the saw firmly to prevent it from jumping off the line. After the saw is well started, hold the work firmly with left hand a safe distance from the saw, and use a full, even stroke. Avoid short, rapid strokes and the application of pressure to the saw. Forcing the saw may cause a crooked cut and difficulty in following the line. If the saw does not cut sufficiently rapid without forcing, it may need reconditioning. Sight along the saw and the line to insure a straight cut. If the saw leaves a line, bend the saw slightly and work it back to the line. Maintain an angle of approximately 45° between the teeth of the saw and the

work. When nearing the end of the cut, use the hand to support the piece being severed, in order to prevent the wood from splitting.

b. Ripsaw.—(1) The ripsaw is used for cutting along the grain; it tears the fibers when cutting across grain. The teeth are filed straight across (fig. 35②) and resemble a chisel point. The teeth are also set for blade clearance. Generally, a coarser saw is used for ripping. A 26-inch saw having six or eight teeth per inch is commonly used.

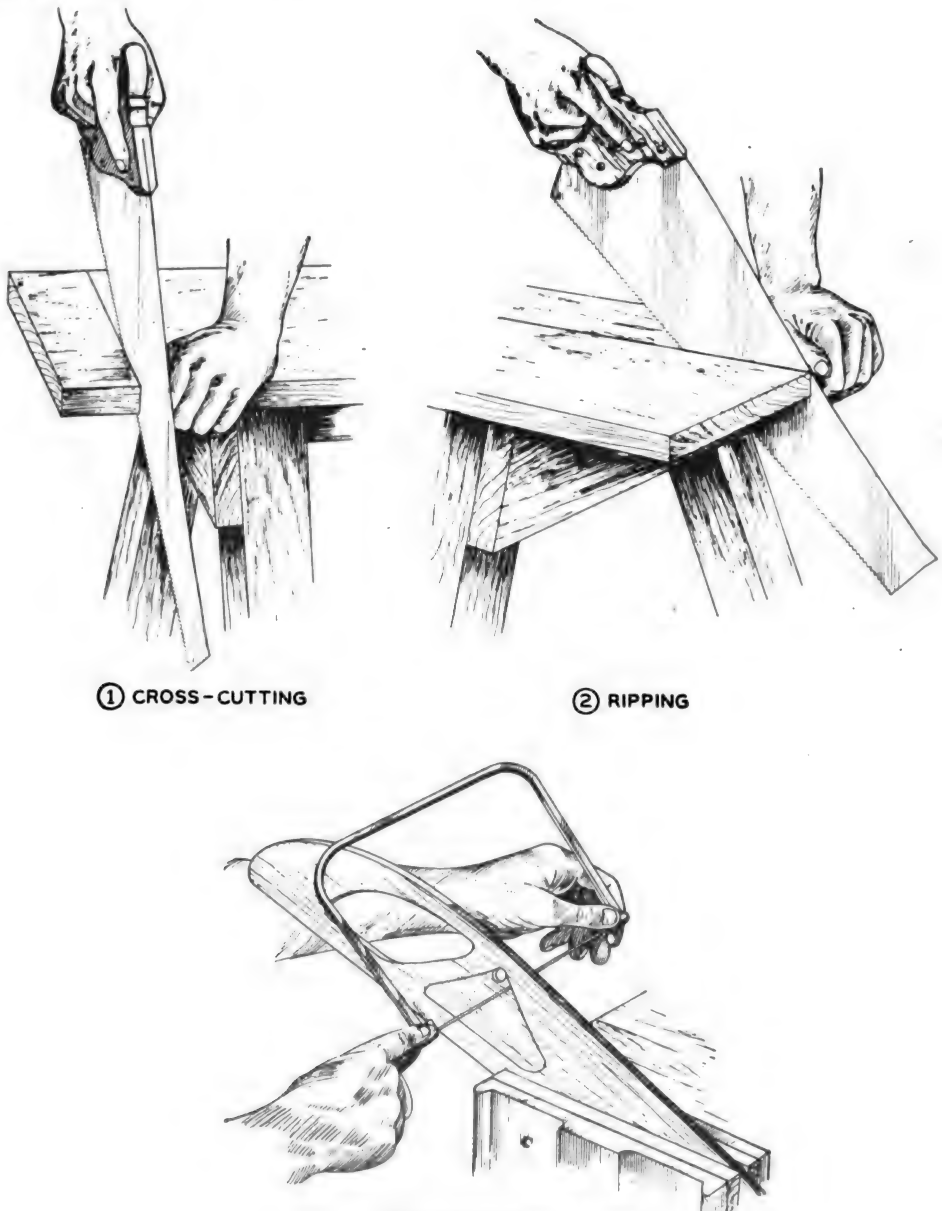


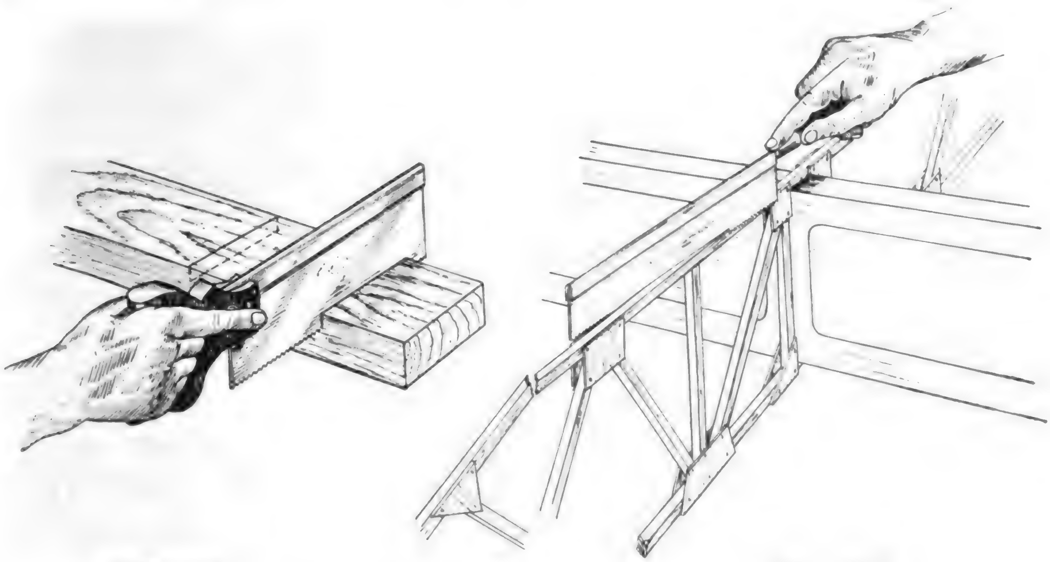
FIGURE 36.—Application of hand saws.

(2) Support the stock (fig. 36②) and operate the saw in a manner similar to crosscutting. If the saw cut tends to close behind the saw, causing it to bind, insert a wedge in the cut to keep it open.

c. Coping saw.—(1) The coping saw (fig. 36③) is especially adaptable for cutting curves and irregular shapes in thin wood. The blade is removable from the frame. When the stock interferes with the free movement of the frame, the blade angle may be changed.

(2) For inside cutting, an entry hole is drilled in the waste portion of the stock, the blade inserted, and then installed and properly tightened in the frame. If the work is held in a vise, both hands may be used to guide the saw. The teeth usually point away from the handle. However, if the stock is supported on a bench or bracket, one hand is used to hold the stock firmly and the other hand is used to operate the saw vertically; in such case the teeth point toward the handle because the cutting stroke is downward.

d. Backsaw.—(1) The backsaw (fig. 37①) is used for fine, light bench work. It has fine crosscut teeth and a thin blade, stiffened by a heavy rib of steel (hence the name "backsaw"). Sizes range from 8 to 14 inches in length. A 12-inch saw with 14 teeth per inch is commonly used.



① Backsaw. ② Dovetail.

FIGURE 37.—Backsaw and dovetail saw.

(2) Start the cut as with an ordinary crosscut saw. After the saw is started, gradually bring the saw down to a horizontal working position to finish the cut.

e. Dovetail.—(1) The dovetail saw (fig. 37② is used for fine sawing. In aircraft work, it is especially useful for cutting scarfs in the repair of wing ribs, bows, etc. The teeth of the dovetail saw are finer than those of a backsaw, otherwise it is very similar to the backsaw.

(2) The dovetail saw is used in the manner of the backsaw. Being lighter and smaller, it may be used in somewhat restricted quarters.

f. Miter.—(1) The miter saw (fig. 38) is simply a large backsaw guided in such a manner as to remain perpendicular to the work while cutting at any of various angles. A graduated sector provides a convenient means of determining the angle of cut. The assembly of the saw, table, and guiding mechanism is known as a miter box. Pieces of equal length may be cut by using a fixed position of the adjustable stop.

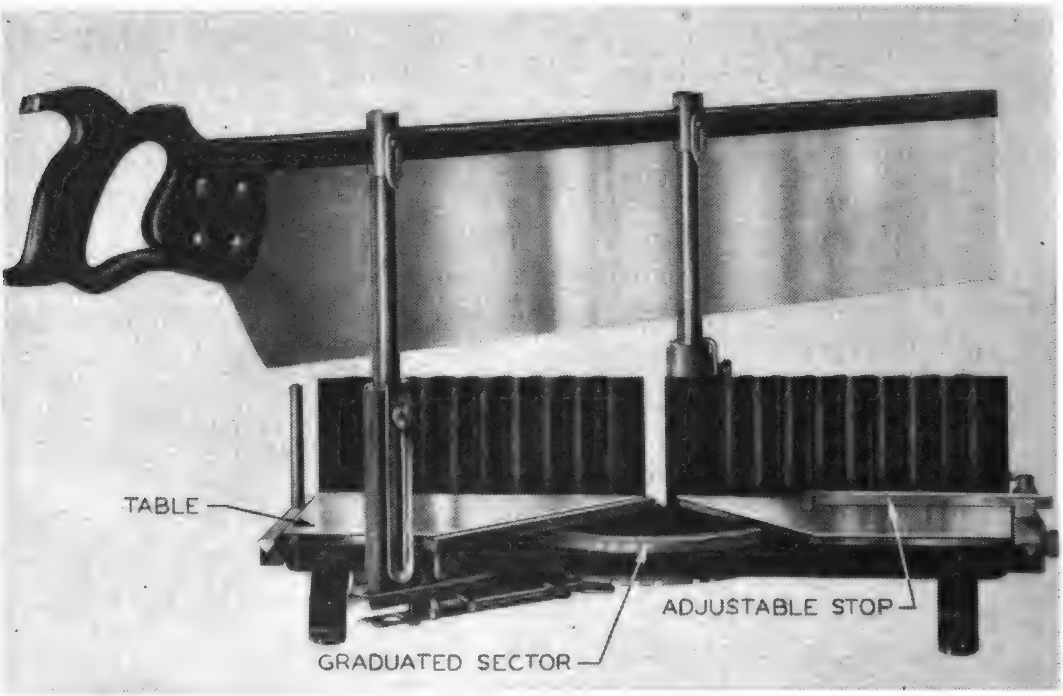
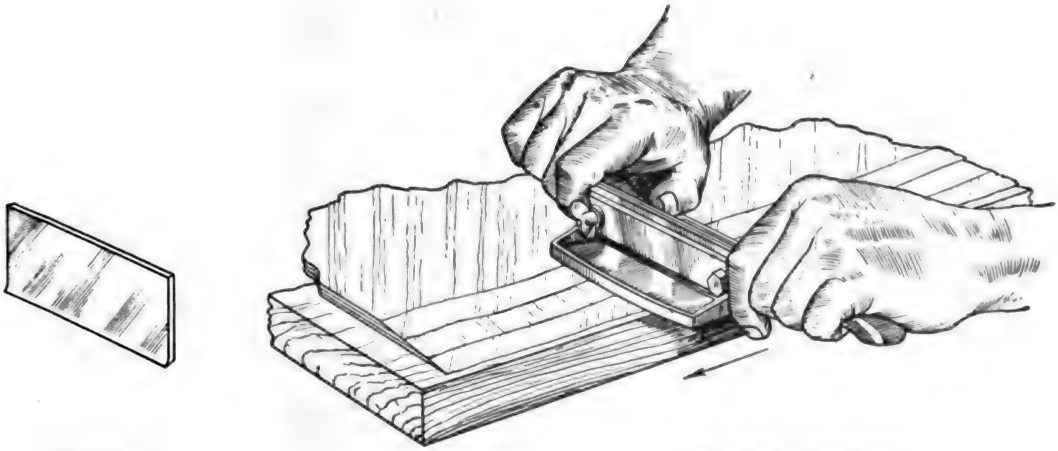


FIGURE 38.—Miter saw.

(2) The miter box cuts very accurately when properly used. It is necessary to hold the work tightly in place while sawing; an inaccurate cut is likely to result if the work moves. Be sure the cut is completed before attempting to remove the stock.

38. Scraper.—*a.* The wood scraper is very useful in smoothing surfaces having the grain running in various directions, where a plane could not be used successfully. The blade of a scraper has a sharply curved cutting edge (fig. 39①) which breaks the shavings abruptly, producing a smooth surface. Two types are available, the cabinet scraper (fig. 39②) and the hand scraper. The cabinet scraper consists of a steel blade held in a metal frame which holds the blade at the proper angle (approximately 70°) with the work. The hand scraper is simply a steel blade, usually 3 by 5 inches. The hand scraper is used to advantage for finishing surfaces inaccessible with the cabinet scraper.



① Blade. ② Cabinet scraper.

FIGURE 39.—Wood scraper.

b. The fine turned edge of the scraper dulls easily and requires frequent sharpening during use. After sharpening the blade, adjust it in the handle to produce a thin shaving. Push the scraper, maintaining a slight angle with respect to the grain in order to produce a slicing effect. When scraping only a portion of the surface, blend the scraped area into the remaining surface by raising the heel of the scraper at the end of the stroke to gradually thin the shaving instead of cutting it off abruptly, thus leaving no mark. When the scraper no longer produces shavings, resharpen the blade. The hand scraper is used in the same manner; hold the scraper to maintain an angle of approximately 70° with the work.

39. Clamps.—*a.* Clamps are used extensively for temporarily holding stock when assembling, working, etc., and especially for applying pressure to stock being glued. Clamps are available in a variety of sizes. Types commonly used are as follows:

(1) The screw clamp, or C-clamp, is available in various sizes. A small size is shown in figure 40①. It is used for a wide variety of holding operations.

(2) The hand screw clamp (fig. 40②) is used mostly in gluing stock face to face, especially when the surfaces are not parallel. A variety of positions of the jaws is made possible by the swivel attachment of the spindle to the jaws.

(3) The bar clamp (fig. 40③) is designed to accommodate assemblies or wide stock. It is adjustable over a wide range, along the full length of the bar. Bar clamps are used mainly in gluing stock edge to edge.

b. The manner of using the various clamps depends largely on the application. Bar clamps and C-clamps are simply adjusted to the work and turned up to the desired tension. These clamps are capable

of exerting considerable force, and they should be turned up cautiously to avoid distorting or disfiguring the work. The hand screw clamp should be carefully adjusted to the work, then tightened by turning the inside or shoulder spindle first, then the back spindle. Each jaw should be flush with its respective surface when the clamp is tight. The clamp is removed by reversing the procedure, that is,

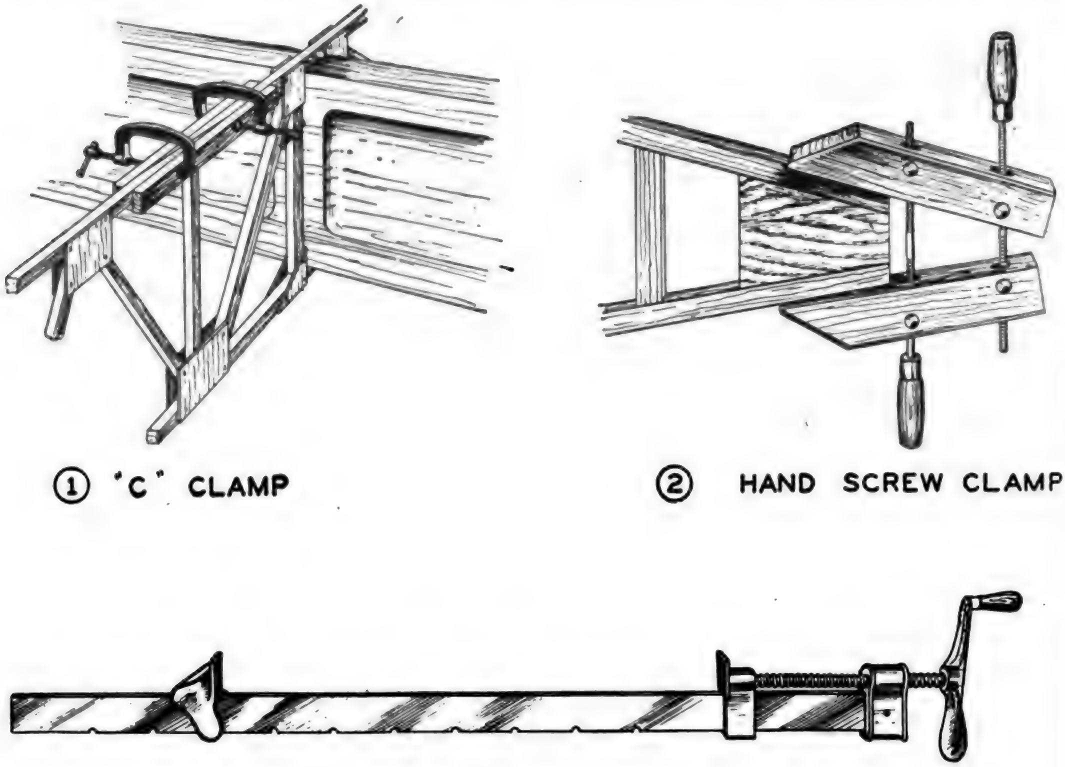


FIGURE 40.—Clamps.

by loosening the back spindle first. Linseed oil applied to the jaws will prevent glue from sticking to them when the clamps are used in the gluing operation. The screws of all clamps should be oiled frequently for easy operation.

40. Screw drivers.—*a. Types.*—(1) The cabinet screw driver (fig. 41①) is most commonly used for general work. Size designations refer to length of blade.

(2) The close quarter screw driver (fig. 41②) is very short, having a 1-inch blade and a short handle. It is adaptable for use in restricted quarters.

(3) The spiral ratchet screw driver (fig. 41③) is designed for rapid driving. It is supplied with three sizes of bits of the type shown, to accommodate various screw sizes.

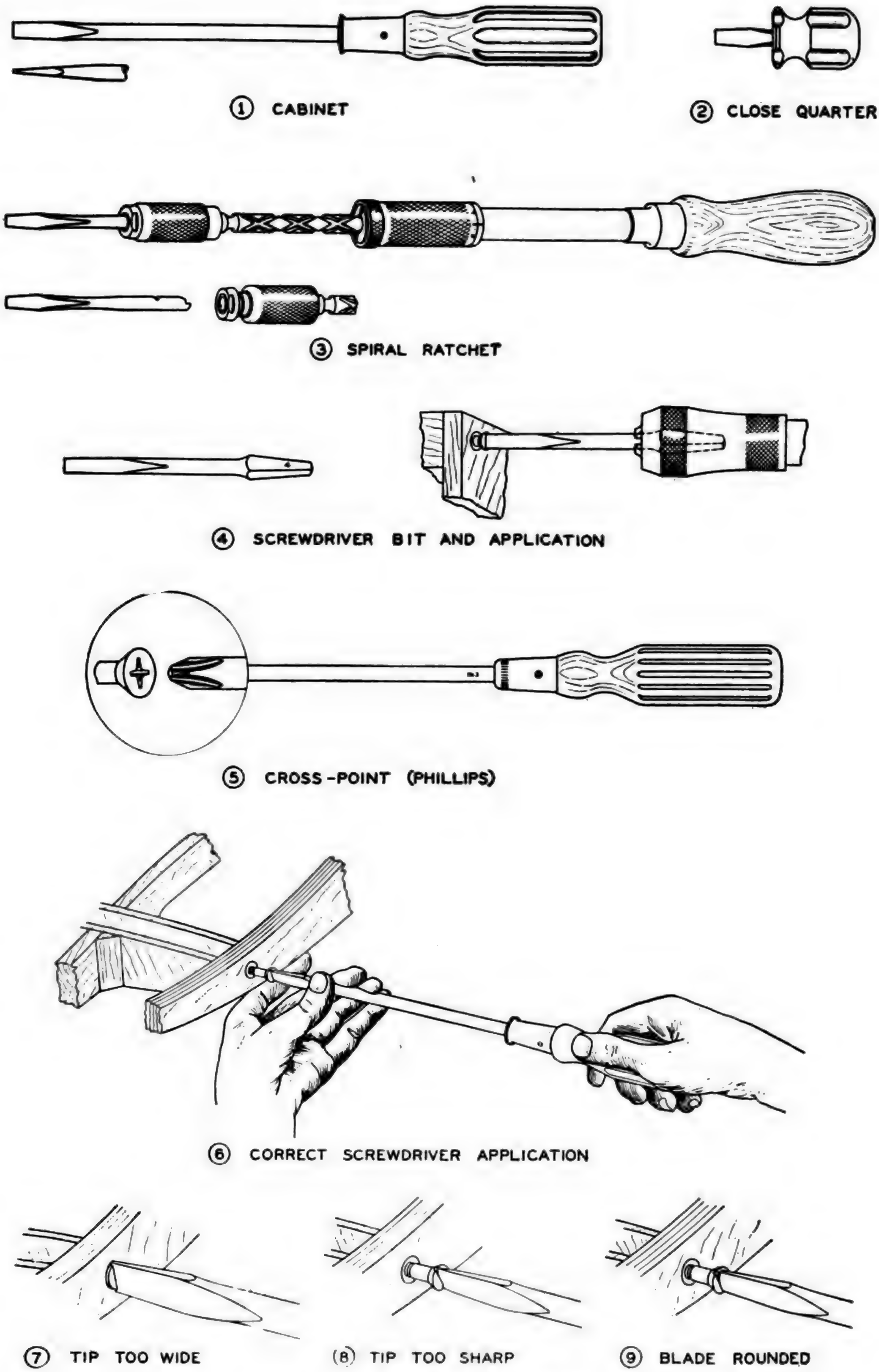


FIGURE 41.—Screw drivers.

(4) The screw driver bit (fig. 41④) is designed for use in conjunction with a bit brace. Considerable leverage may be obtained by this arrangement. It is used mostly for driving large screws where considerable turning force is required.

(5) The cross-point screw driver (fig. 41⑤) is designed for use with special cross slot screws. The Phillips type is shown in figure 41⑤. The Reed and Prince type is another form of cross-point screw driver.

b. Selection and use.—The screw driver selected should be adaptable for the application. It should be as long as is convenient. More turning force may be exerted with a long screw driver and there is less danger of the screw driver slipping from the slot. The tip should fit the slot and should not be wider than the screw head (fig. 41⑥). A tip that is too wide (fig. 41⑦) will mar the work. especially when driving a flathead screw. The sides of the tip should be nearly parallel and fit the slot as snugly as possible. A pointed or rounded tip will rise out of the slot easily (fig. 41⑧ and ⑨) and mar the screw or the work. When driving, the screw driver should be lined up with the screw and sufficient pressure applied to prevent the screw driver from slipping out of the slot. One hand should be used to control the tip of the screw driver. If it is necessary to hold the work, the hand should be held in a safe position to avoid injury from the screw driver if it should slip.

41. Wood rasp and file.—The wood rasp and wood file are occasionally used in place of edge tools for removing excess stock. The rasp has very coarse triangular shaped teeth and is employed in roughing out curved outlines. The wood file makes a finer cut than the rasp and is used for finishing and for removing a small amount of stock when fitting component parts of an assembly. It is used with a forward, sidewise motion.

42. Hammer.—The claw hammer (12-ounce) is most commonly used for general purposes in the wood shop. It is adaptable for both driving and drawing nails.

a. Driving nails.—When driving nails, hold the hammer firmly near the end of the handle to obtain maximum striking force. Strike the nail squarely with the face of the hammer to avoid bending the nail and marring the wood. Do not strike with the side or cheek of the hammer as it is the weakest part and may be damaged.

b. Drawing nails.—When a nail is to be drawn, slide the claw under the head of the nail and pull on the handle. Place a piece of scrap stock between the hammer and work when possible, to prevent damage to the surface of the work. If the nail is only partly drawn

when the handle is pulled to a position at right angles to the work, place a thicker piece of scrap stock between the hammer and work.

SECTION VI

WOODWORKING MACHINES AND OPERATIONS*

43. General.—In many instances, operations performed with hand woodworking tools may be accomplished more quickly and accurately on specially designed woodworking machines. While numerous types of machines are available, those most adaptable for general wood shop use include the circular saw, band saw, jig saw, jointer, surfacer, shaper, boring machine, and lathe.

44. Circular saw.—*a. Types and structural features.*—The circular saw is one of the most used machines in the shop. While it is employed principally for ripping, beveling, crosscutting, and mitering, various other operations, such as grooving, dadoing, rabbeting, molding, etc., can also be performed on this machine by using special attachments and set-ups. Circular saws are made in a variety of types and sizes. The most common are the universal saw and the variety saw. The universal type (fig. 42) is equipped with two arbors which permit mounting both rip and crosscut blades, either of which is brought into use by simply turning a hand wheel controlling the positions of the arbors. The variety saw (fig. 43) employs a single arbor and is generally fitted with mortising and boring attachments. The main structural features of either machine are similar, however, and include the arbor, saw blades, table, ripping fence, crosscutting and mitering fence or gage, and a substantial base.

(1) The arbor carries the saw blade and the various attachments designed for the machine. The blade end is threaded left hand and fitted with a fixed collar, a loose collar, and a nut. A left-hand

*Illustrations of woodworking machines (figs. 42 to 47, 59, 60, 62 to 64, 72 to 76, 79, 80, and 82 to 86) have been reproduced by permission of the Oliver Machinery Company.

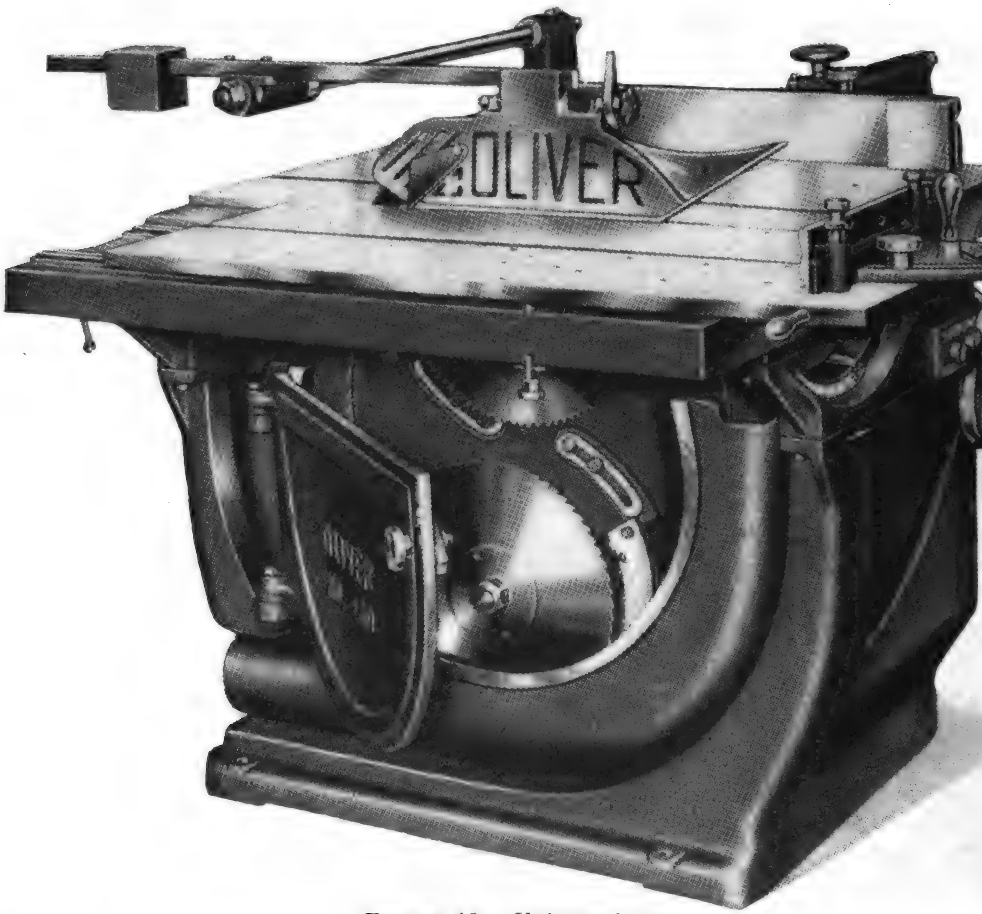


FIGURE 42.—Universal saw.

thread is employed in order that the blade, which rotates to the right, will remain tight when operating. The opposite end of the arbor is threaded and fitted to accommodate drills, mortising chisels, etc., on machines designed for these attachments. On machines employing a direct drive, the shaft of the motor is fitted out as an arbor. A double arbor machine of this type usually has two separate motors mounted on a yoke (fig. 44). Both motors are controlled by one switch, but only the motor in cutting position operates.

(2) The saw blades commonly used are of three general types (see fig. 45): ①, crosscut, ②, rip, and ③, miter. The tooth and gullet shapes shown are considered best for general purpose sawing.

(*a*) Tooth spacing on crosscut saws 12 to 16 inches in diameter ranges from $\frac{7}{16}$ to $\frac{7}{8}$ inch from point to point, depending on whether the saw is to be used for coarse or fine work. A blade having 100 teeth in the 14-inch size is recommended for general work.

(*b*) For general requirements, tooth spacing of the ripsaw ranges from $\frac{3}{4}$ inch to $1\frac{3}{4}$ inches depending on the coarseness or fineness of the work. Tooth spacing of $1\frac{1}{4}$ inches between points is considered suitable for work up to 2 inches.

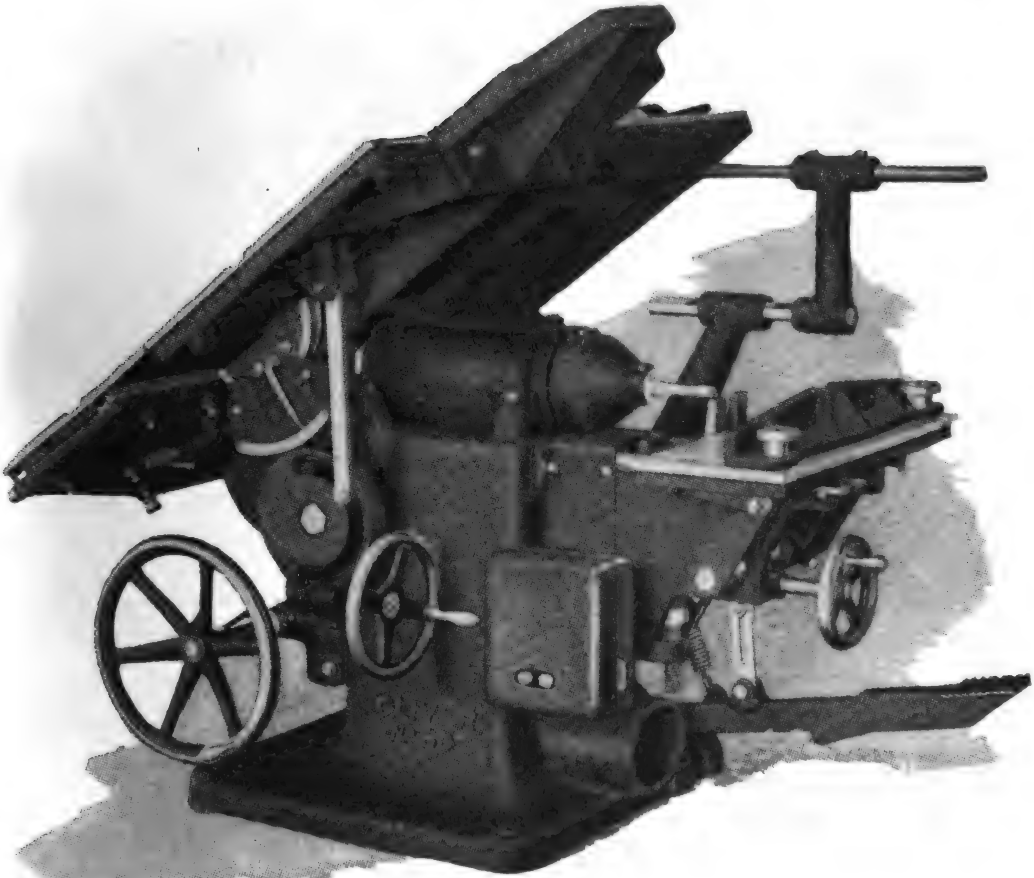


FIGURE 43.—Variety saw.

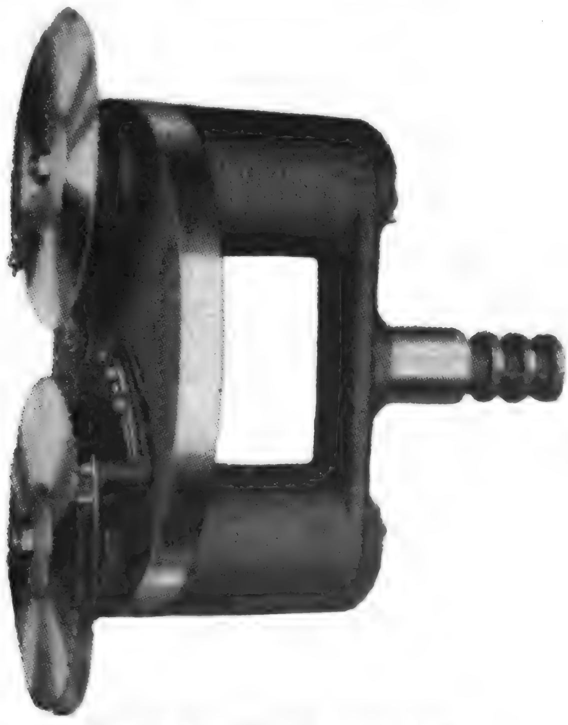
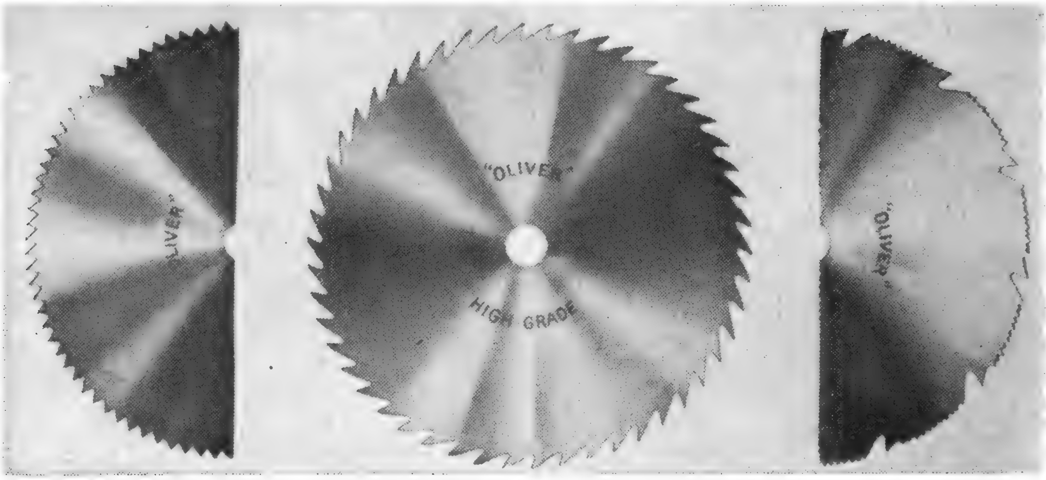


FIGURE 44.—Double arbor yoke.



① Crosscut. ② Rip. ③ Miter.

FIGURE 45.—Circular saw blades.

(*c*) The miter saw is also referred to as a combination saw or planer saw. It is equally adaptable for crosscutting, ripping, and mitering and is generally used on a single arbor machine to eliminate frequent blade changing. The cutting teeth are similar to those of a crosscut blade. However, ripping teeth are located at regular intervals throughout the circumference of the blade which serve to clear chips from the cut and provide the smooth cut of a ripsaw. Miter saws ordinarily are not made with the teeth set for clearance; instead, the blade is ground several gages thinner at the center than at the rim. A very smooth cut can be obtained with the miter saw, but it has very little clearance and should not be crowded or cramped when cutting.

(3) The table of the universal saw is bolted securely to the base and remains horizontal in use. This is the preferred arrangement since the operator has full control over the stock being worked. On the variety saw, however, the table is mounted so that it may be tilted up to 45° for beveling and mitering, and also raised and lowered for regulating the depth of cut. Table construction is of two general types: one-piece type, and two-piece type with movable section.

(*a*) The one-piece table is of solid construction. It is fitted with a detachable throat piece which is removed to provide additional space when changing saw blades and mounting the various special blades and cutter heads.

(*b*) The two-piece table has the portion to the left of the saw blade mounted on ball or roller bearings and is easily moved back and forth past the blade. Pulling this section forward provides additional table space in front of the blade for handling wide stock. The section is held stationary by a pin when desired. No throat piece is provided;

instead, the movable section may be slid away from the blade and clamped in that position when changing blades or using special attachments.

(4) The ripping fence serves as a guide when ripping, beveling, etc. It is attached to the table usually to the right of the saw, although it may be used on either side. The simpler types slide along a bar or groove at the front of the table and are clamped in the desired location. The type shown in figure 46 is secured to the table and is equipped with a micrometer attachment for extremely accurate settings. Usually a scale graduated in inches and fractions is engraved in the top of the table, eliminating the necessity of using a rule when setting the fence the desired distance from the blade. The fence shown in figure 46 can be tilted up to 45° for beveling; some types remain fixed perpendicular to the table.

(5) Two types of gages are used when crosscutting and mitering: the cut-off gage and the universal miter gage.

(*a*) The cut-off (fig. 47①) is used on tables having a movable section (fig. 42). It is attached to the movable part of the table either in a fixed position at right angles to the saw or in a manner allowing for angular settings. The gage is quickly and accurately

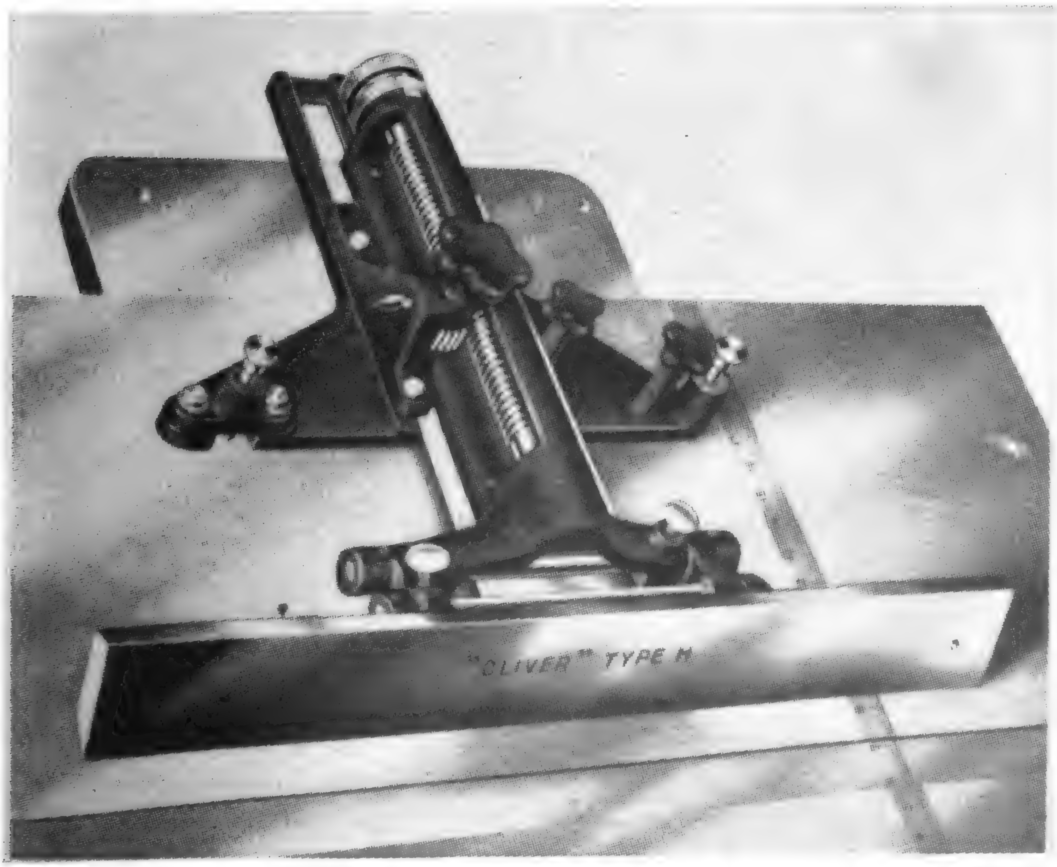
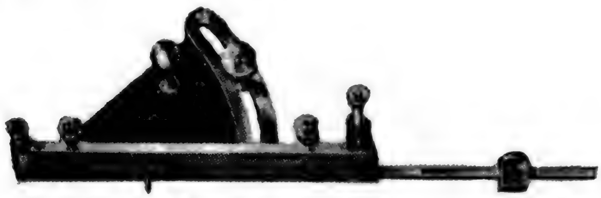


FIGURE 46.—Ripping fence.

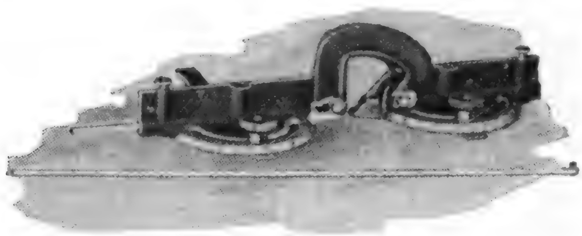
located at the more common angles by means of a taper pin set into properly located holes in the table. Other settings are obtained directly from markings on the table. Metal stop rods are usually furnished to be used with the gage when cutting a number of pieces to length.

(*b*) The universal miter gage (fig. 47②) slides in the grooves in the table on either side of the blade. The universal and variety saws are usually equipped with two gages which may be yoked together (fig. 47③) and used simultaneously to provide better control when working large stock.



① Cut-off.

② Universal miter gage.



③ Two gages yoked together.

FIGURE 47.—Cut-off and universal gages.

(6) Safety devices generally employed include a saw guard, splitter, and an "antikick-back device." The saw guard covers the blade and is usually designed to ride over the work. The splitter bar is located back of the blade to prevent the saw kerf from closing and grabbing the blade, causing the board to be thrown toward the operator. The device hinged to the splitter is designed to prevent kick-back in case the blade becomes wedged in the cut. These devices should be used whenever possible and extreme care exercised to prevent serious accidents.

(7) The base incloses as much of the mechanism as possible. Openings are provided for accessibility to working parts and connection to an exhaust system for removal of dust and chips.

b. Operation.—(1) The following are basic operations most generally performed on the circular saw. If it is necessary to change blades, remove the throat piece or slide the movable section of the two-piece table away from the blade. Wedge a piece of wood against the teeth of the blade (fig. 48) and loosen the nut, turning right. Install new blade and tighten nut securely, wedging the blade

as for removing it. As the hole in the blade is slightly larger than the arbor, it will tend to run off-center. For this reason it is good practice to mount the blade with the same portion up each time. The blade will then run perfectly true after it is once jointed and filed. Be sure the blade is securely fastened to the arbor and will turn freely before operating the saw.

FIGURE 48.—Removing saw blade.

(*a*) *Ripping.*—Attach the ripping fence to the table and set it the desired distance from the blade, using the scale engraved on the table or a rule for measurement. Make fine adjustments with the mi-

crometer attachment, if available, and clamp the fence securely in place. Adjust the table or the arbor until the blade projects not more than ⅛ inch above the stock being cut. See that the splitter is in the proper position back of the saw, and that the guard is in place. Before attempting to rip any stock, the edge to be held against the fence must be straight. If necessary, straighten one edge with a plane or power jointer. It is also necessary that the stock lie flat on the table; crooked or warped stock will only tend to bind the blade during the cutting operation. Hold the straight edge against the fence and push the stock against the saw blade with a firm, even motion (fig. 49). The position of the hands is important. Use the left hand

FIGURE 49.—Rip sawing.

to hold the stock down against the table and also against the fence: control the movement of the stock with the right hand. When ripping pieces too narrow to permit the hand to pass safely between the fence and the blade, either use the push stick (fig. 50), or saw part way from each end of the piece (fig. 51). In ripping thin stock, such as veneer, place a piece of scrap wood over the top of the veneer to hold it tightly against the table (see fig. 52).

(*b*) *Resawing.*—Sometimes it is necessary to saw stock edgewise to reduce its thickness. The operation is similar to ripping and is referred to as resawing. Set the ripping fence for the width of stock desired and proceed as in ripping. If the stock is wider than twice the maximum saw cut, turn the piece end for end and make a second cut (fig. 53), holding the same face against the fence. When two cuts

FIGURE 50.—Use of push stick.

FIGURE 51.—Ripping part way from each end.

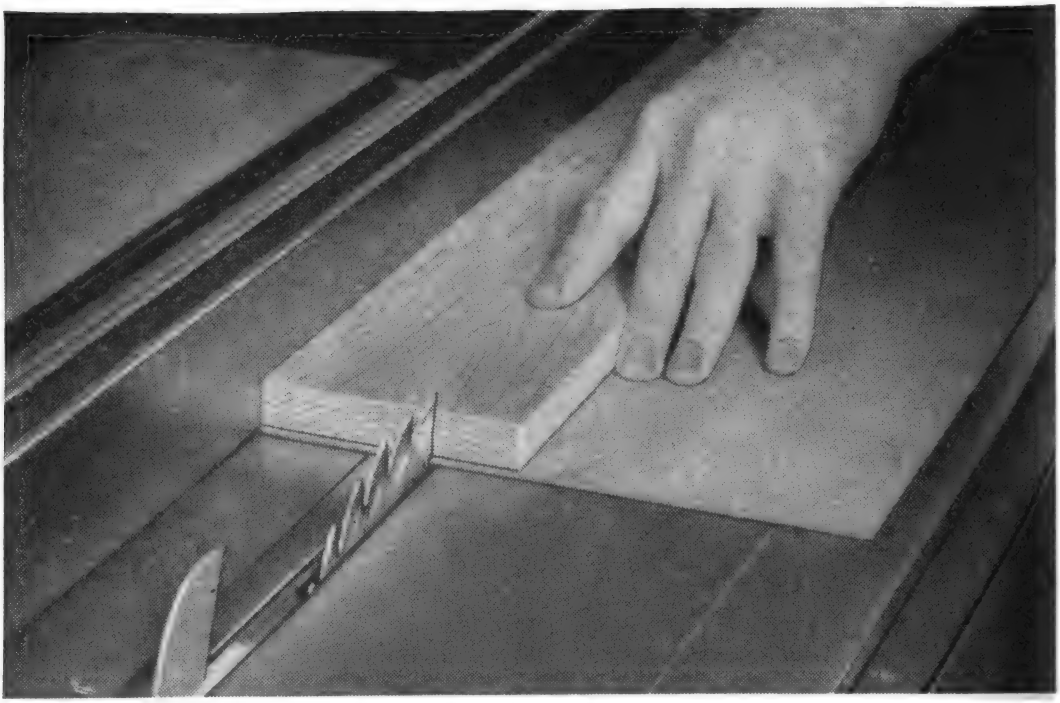


FIGURE 52.—Ripping veneer.

FIGURE 53.—Resawing.

are necessary, each should be slightly more than one-half the width of the piece. If two cuts of maximum depth are insufficient, complete the operation on a band saw.

(*c*) *Beveling and chamfering.*—Beveling and chamfering can be accomplished by tilting the ripping fence, tilting the table, or tilting the arbor. If the first method is used, tilt the ripping fence to the desired angle and set it as close to the blade as possible in order to cut a full bevel. Adjust the table or arbor so the blade cuts through the board. Hold the board tightly against the fence when making the cut; if it slips away from the fence the bevel will be inaccurate. If the second method is used (fig. 54), tilt the table to the desired

FIGURE 54.—Beveling.

angle and attach the ripping fence to the left of the blade. A sliding T-bevel may be used to check the setting (fig. 55), especially when copying angles. As most tables tilt left, the board will then have a tendency to rest against the fence; if the fence were on the right, the stock would tend to slide against the blade, causing it to bind or cut unevenly. On tilting arbor machines, tilt the blade to the desired angle and proceed as in straight ripping.

(*d*) *Crosscutting.*—Crosscutting involves the use of either the miter gage or the cut-off gage. Set the miter gage for a 90° cut and adjust the table or the arbor so that the blade projects only slightly above the stock being cut. A simple way to set the miter gage accurately is to turn it upside down in the table slot and slide it up against the front of the table. The table slots are always milled at right angles to the front of the table. Hold one edge of the stock against the gage tightly and push it past the blade. For accurate

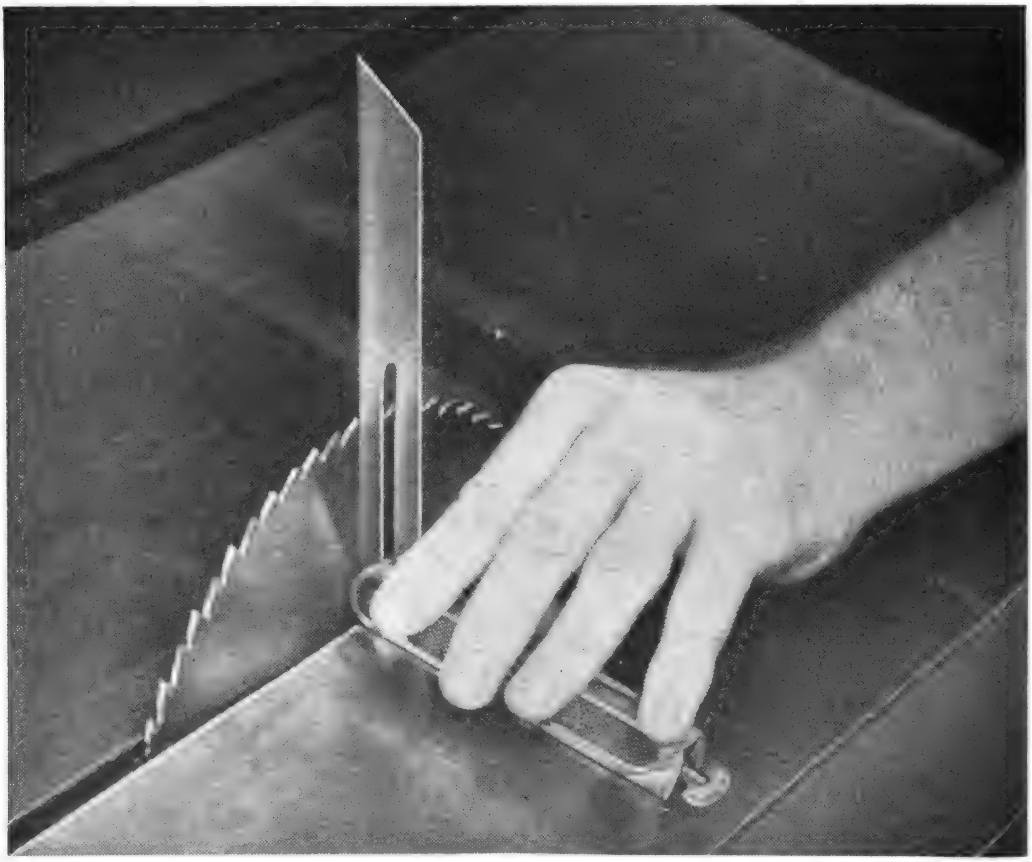


FIGURE 55.—Setting table angle by means of sliding T-bevel.

squaring, the edge against the gage must be perfectly true. In crosscutting wide stock, attach the cut-off gage to the movable section of the table and set it at right angles to the blade. Pull the sliding section back to accommodate the width of stock being cut. In order to prevent stock from sliding sideways and producing an inaccurate cut, attach a stop block to the gage for the stock to butt against. For crosscutting long pieces, yoke the two miter gages together and use both simultaneously.

(*e*) *Crosscutting to length.*—Several methods are commonly used to cut a number of pieces to length. For short lengths, attach a

clearance block to the ripping fence (fig. 56) and set it for the desired length. Never use the ripping fence without the clearance block as the severed piece may become wedged between the blade and the fence. Another method is to attach a stop rod to the miter gage and to set it the desired distance from the blade. Butt the stock against the stop rod and make successive cuts. If the pieces are already roughly cut to length, square one end, using the miter gage to the right of the saw; then cut to exact length, using a stop rod in the gage to the left of the saw.

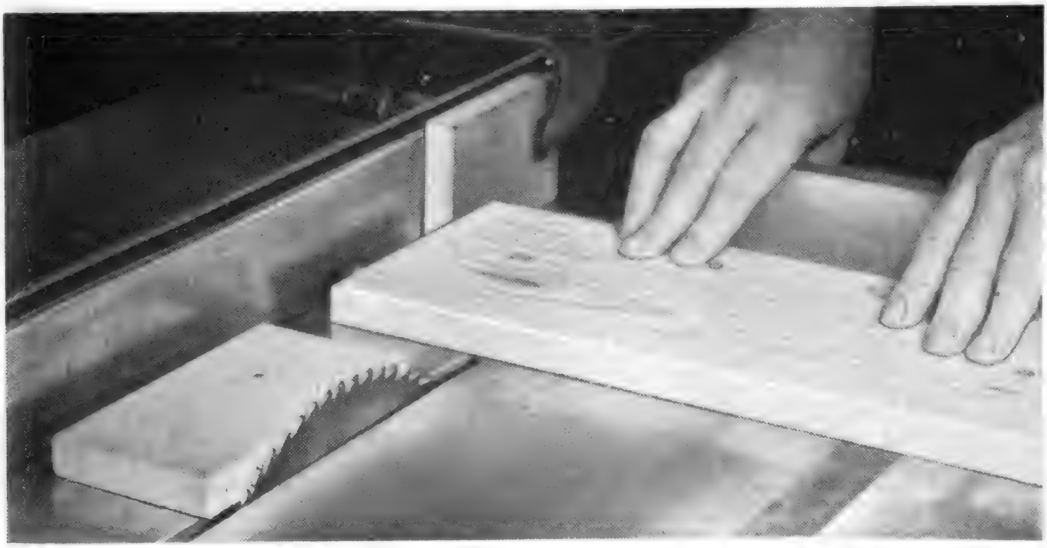


FIGURE 56.—Crosscutting to length.

(*f*) *Mitering.*—Either a crosscut or combination blade should be used in making miter cuts. Set the gage used (cut-off or universal) at the desired angle. The cut-off gage can be located at the more commonly used angles by means of taper pins fitted into holes in the table. This insures accurate setting. The miter gage may move slightly as the screw is tightened; therefore, care should be exercised to prevent inaccurate settings. A sliding T-bevel may also be used to set the gage when copying angles. After the gage is set, proceed as in crosscutting. The stock may have a tendency to creep if it is not held tightly against the gage or clamped in position. The result is an inaccurate cut.

(*g*) *Grooving.*—The ordinary ripsaw and crosscut saw may be used to cut grooves by making a series of successive cuts (fig. 57). However, the better method is to use a dado head (fig. 58), especially for wide grooves. The dado head can be set to cut grooves from ⅛ inch to 2 inches wide and is equally adaptable for cutting along the grain or across the grain. One dado saw will produce a cut

⅛ inch wide; two saws will cut a ¼-inch groove. For wider grooves additional cutters of various thicknesses are mounted between the saws to make up the width of groove desired. When cutting along the grain, proceed as in ripping, using the ripping fence as a guide. Use the ripping fence also as a stop when cutting across grain.

FIGURE 57.—Grooving with ordinary saw blade.

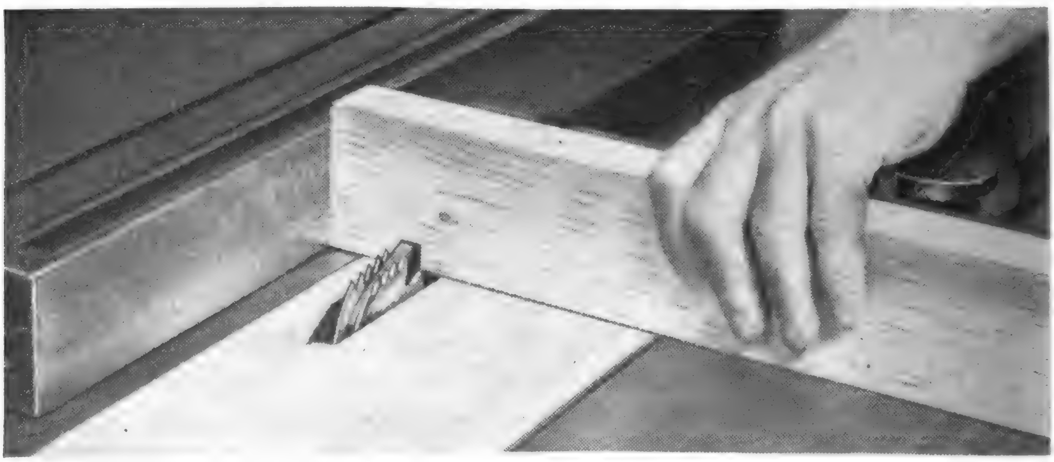


FIGURE 58.—Grooving with dado head.

(2) The circular saw is a very dangerous machine and can cause serious injury to both the operator and bystanders. Not only is there danger of being cut by the blade, but serious injury can result from boards thrown toward the operator. This latter is referred to as "kick-back" and may be caused by a dull blade, a blade insufficiently

set, or improper contact of stock with the table, guides, or fence. Also, if a splitter is not used to keep the saw cut open, the wood is likely to grab the back of the blade and be thrown forward with great force. It is therefore necessary to exercise care in using the circular saw and observe the following safety rules:

(*a*) Pay strict attention to the machine; avoid looking around or carrying on a conversation while operating the machine.

(*b*) Use the guards, guides, featherboard, push stick, etc., whenever possible.

(*c*) Use only saws properly sharpened and set.

(*d*) Stop machine when making adjustments.

(*e*) Keep the floor clean around the machine to prevent slipping or tripping.

(*f*) Avoid sawing freehand, that is, without the aid of a fence, gage, or other suitable guide. Stock must have one straight edge and lie flat on the table, otherwise it will cause binding.

(*g*) Adjust the machine so the blade projects not more than 1/8 inch above the stock being cut.

(*h*) Do not stand in line with saw; have a helper remove stock if necessary.

(*i*) Do not use the ripping fence as a guide when crosscutting; the severed piece may jam the blade.

(*j*) Avoid wearing loose fitting clothing; it may get caught in the machine and cause serious injury.

45. Band saw.—*a. Construction.*—The band saw (fig. 59) is constructed in a wide variety of sizes and types depending on its use. The type most adaptable for the wood shop is referred to as a band scroll saw. It is designed particularly for cutting curved outlines and lines not parallel to an edge. Essentially, a band saw consists of a table, wheels, guides, saw blade, and suitable guards.

(1) The table of the larger machines is generally in two parts: a small stationary section, and a larger section which can be tilted up to 45° one way and up to 10° the opposite way. The opening for the blade is fitted with a removable soft metal or wood throat piece which prevents damage to the blade in case of blade breakage.

(2) The wheels carry and drive the blade. Motive power is supplied through the lower wheel which is usually directly attached to the driving motor. The upper wheel may be adjusted vertically for regulating tension on the blade, and also tilted through a range of several degrees in order to "track" the blade properly on the wheels. This adjustment is very sensitive, and therefore only a slight movement is necessary to affect proper tracking of the blade. Most ma-

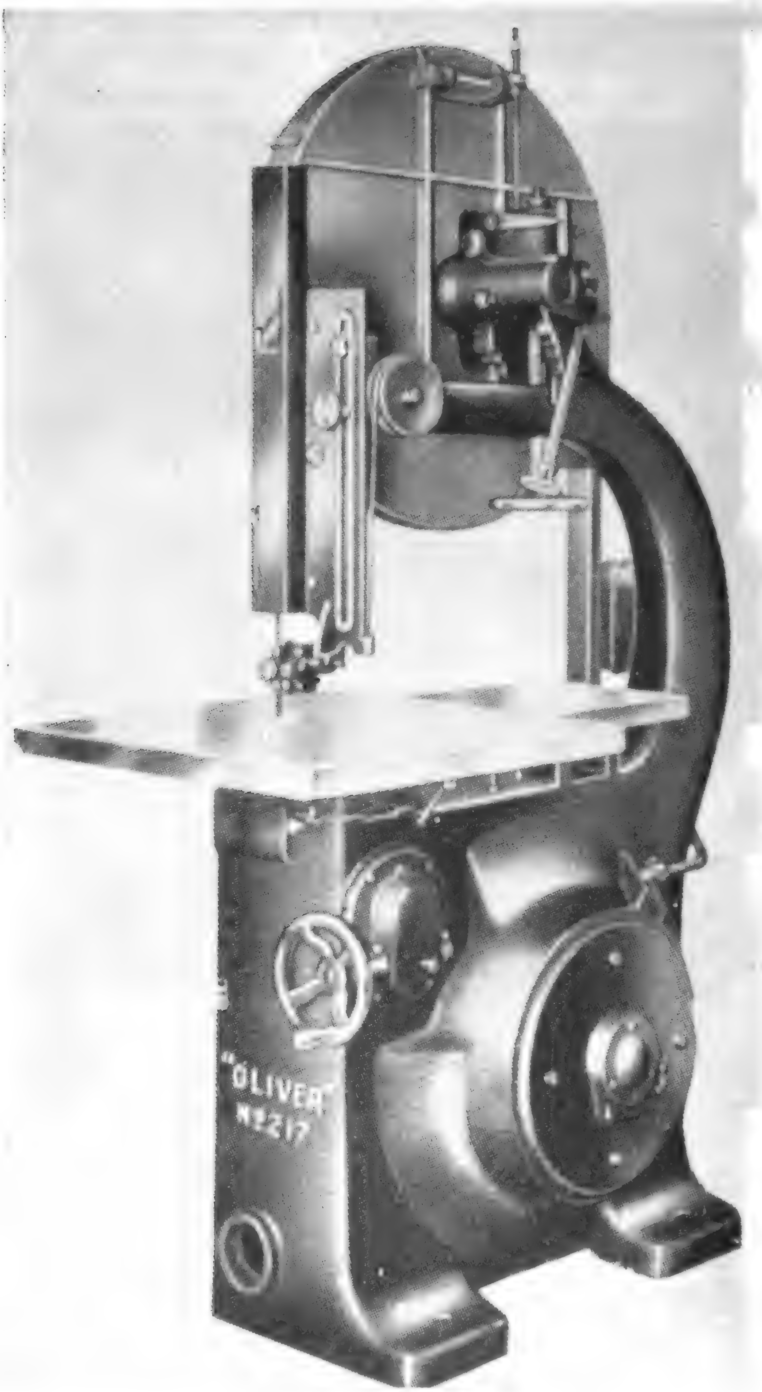


FIGURE 59.—Band saw.

chines are equipped with a brake to shut off the power and stop the saw in case of emergency. The size of the wheels determines the size or capacity of the machine. A 30-inch saw, for example, has 30-inch wheels and will have a capacity of 30 inches minus the space occupied by the rear saw guard.

(3) The purpose of the guides is to steady the blade and hold it in position against the thrust of the work. Guides are made in a wide variety of designs. The type shown in figure 60 consists of a ball bearing roller at the back of the saw blade and a set of jaws at the

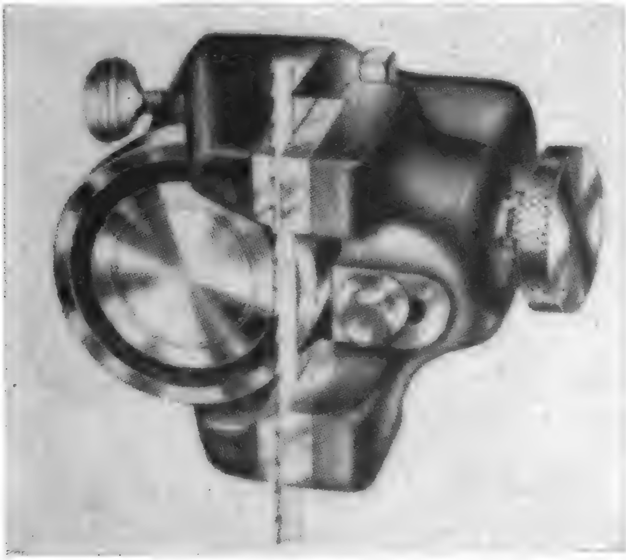


FIGURE 60.—Band saw blade guides.

sides. The roller opposes the thrust of the work while the jaws prevent the blade from being twisted out of alinement. Two guides are employed on each machine, one below the table and one above. The lower guide is fixed in position. The upper guide may be raised and lowered, and is positioned directly above the work when cutting. A screw opens and closes the jaws of the guides which should be adjusted to provide a sliding fit for the blade. Only the teeth of the blade should project from the jaws after adjustment. The roller should be positioned so it barely touches the back of the blade and rotates only occasionally, with the blade running freely. Both upper and lower guides are adjusted alike, and the rollers of both should rotate the instant stock is pushed against the blade, otherwise the adjustment is not correct.

(4) Scroll band saw blades range in size usually from ⅛ to 1 inch in width; wider blades, however, are available. Blades having 4 to 5 teeth per inch are preferable for general cutting except with hardwood, in which case a blade with 6 to 8 points proves more efficient.

The gage or thickness of blade should be in proportion to the size of the wheels and the nature of the work. As a general rule, 21 or 22 gage should be used on 30-inch wheels. Heavy gage blades are not pliable enough on small wheels and are more likely to crystallize and break than the thinner gage bands.

(5) The band saw is so guarded as to be one of the safest woodworking machines to operate. The blade is almost totally inclosed throughout its length. The upper wheel guard travels with the wheel and the blade guard above the table is attached to the upper guide and also moves with it.

b. Operation.—(1) If it is necessary to remove and replace the blade, remove the steel pin in the slot in the table, open the wheel guards, and lower the upper wheel to release the tension on the blade. Grasp the blade with both hands, lift it from the wheels, and carefully coil it before putting it away. If a wider blade is to be installed, slide the guide wheels back out of the way so as not to interfere with the installation of the new blade. Carefully uncoil the blade to be used; if the teeth point in the wrong direction, turn the blade inside out so the teeth will point down toward the table. Slide the blade into the slot in the table, over the top wheel, and directly under the lower wheel. Raise the upper wheel to apply the proper tension to the blade. Too much tension will cause the blade to break easily; too little tension permits it to wobble and twist, and to be easily pulled from the wheels when backing the blade from a cut. Usually machines are equipped with a tension device indicating the proper tension. A wide blade requires greater tension than a narrow one. After obtaining the proper tension, turn the wheels by hand and tilt the upper wheel one way or the other until the blade runs in the middle of the rim. Adjust the guide wheels so that they barely touch the blade when it is idling; adjust the jaws until just the teeth project. The teeth must project, otherwise they would be damaged because of the set (alternate teeth bent outward). The guide wheels should be kept well oiled so they revolve freely, otherwise they may become grooved by the back of the saw. After all adjustments are made, turn the wheels by hand to see that all parts move freely before turning on the power and running the machine.

(*a*) *Sawing curved outline.*—Mark the outline on the stock to be cut with a clear, smooth line. If a number of similar pieces are to be cut, it is best to make a pattern of cardboard or plywood, or to cut a stencil in sheet metal and then to transfer the outline to each piece. Sometimes several pieces can be fastened together by nails or wooden dowels and cut simultaneously. The dowels or nails should be located in the waste portion of the pieces. If nails are used,

drive them from the top so they may be plainly seen and avoided in sawing. Examine the outline to determine the procedure to follow in making the cuts and also to determine the size of blade to use. In general, the following rule can be applied: A 3/8-inch blade may be used to cut curves as small as 2½ inches in diameter, a ¼-inch blade for curves 2 inches in diameter, a 3/16-inch blade for 1½-inch curves, and a 1/8-inch blade for 1-inch curves. Inside curves less than 1 inch in diameter should be cut with an auger bit before the stock is sawed. Cut as close to the outline as possible (fig. 61), leaving a

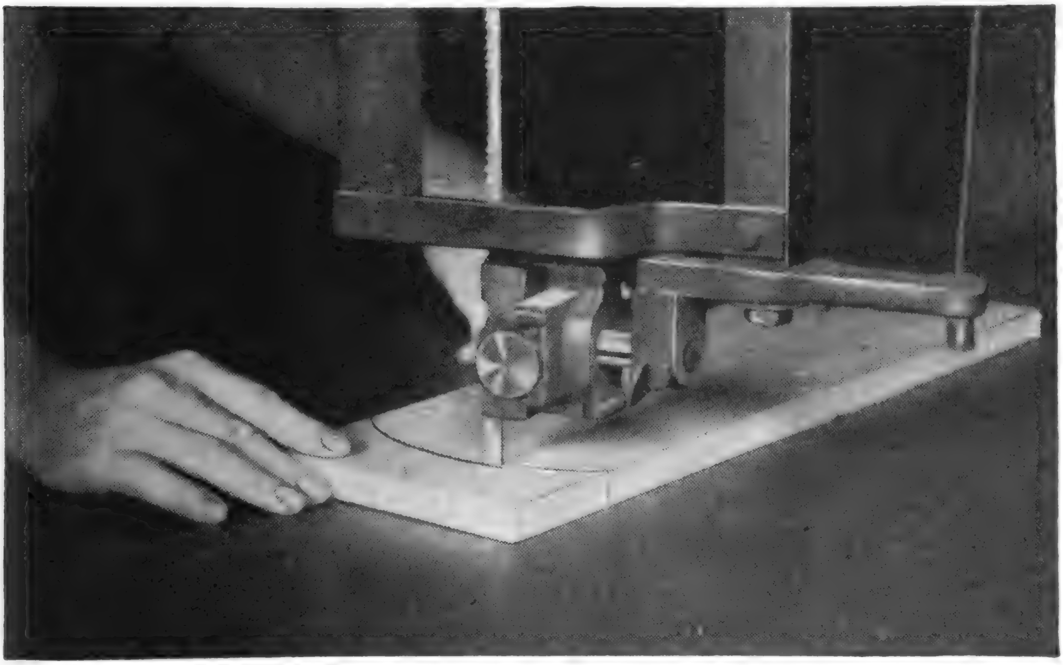


FIGURE 61.—Sawing curved outlines.

minimum of stock to be removed in finishing. Avoid backing a saw out of a cut, if possible, as the blade is easily pulled from the wheels. Either make one complete cut over the entire outline or guide the blade to an outside edge.

(*b*) *Resawing.*—Scroll band saws are not ordinarily equipped with a resawing device. An ordinary ripping fence or improvised guide can be used instead. The board to be cut is first squared on one face and two edges. Two cuts are then made on a circular saw as previously described (par. 44*b*(1)(*b*)). The remaining stock is then removed on the band saw. The two circular saw cuts form a guide which is easily followed.

(2) The band saw is well guarded and is a relatively safe machine to operate. The following precautions should be observed:

(*a*) Use only a blade that is sharp and properly set. Clean blade with kerosene immediately, should it become coated with pitch.

(*b*) Clear floor around machine of all scraps and obstructions.

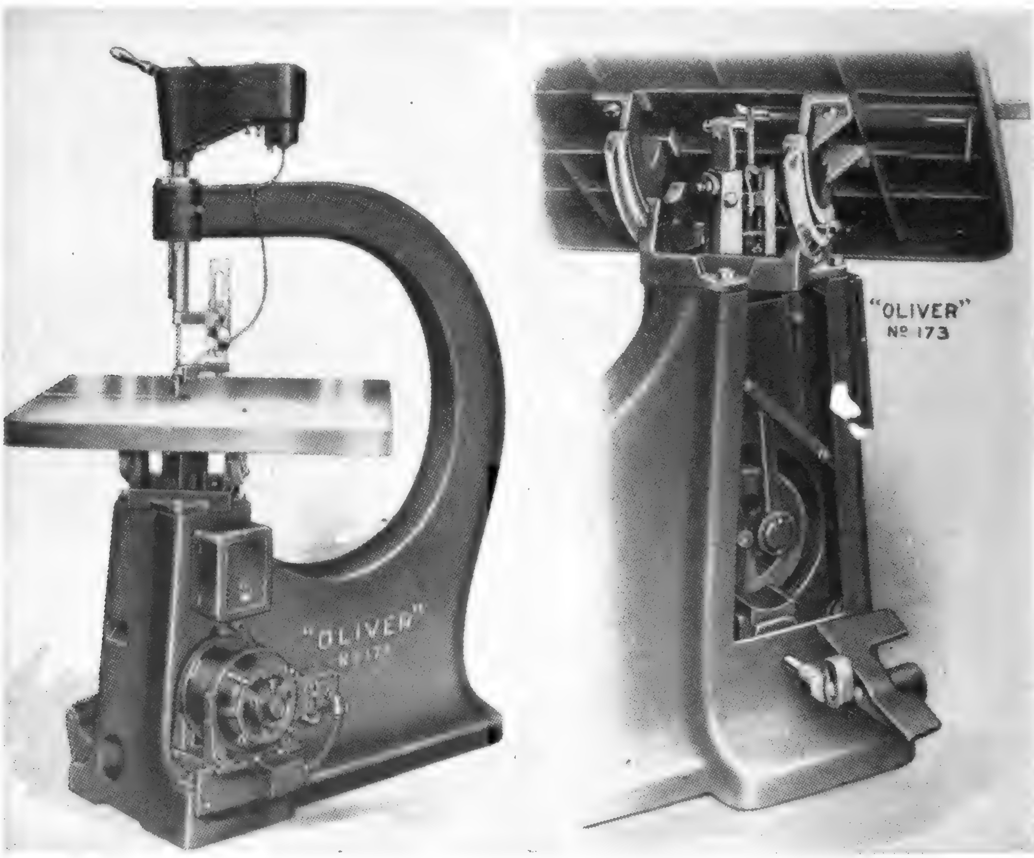
(*c*) Fasten all guards properly in place.

(*d*) Avoid backing saw out of cut when possible; if necessary, back it out slowly and exercise care to avoid pulling blade from wheels.

(*e*) Do not use a worn throat plate; chips are likely to fall through and lodge between the blade and lower wheel, breaking the blade.

(*f*) Adjust guide post as close to upper surface of stock as possible. A guide too high leaves part of the blade unguarded and more easily broken.

(*g*) Wear snug fitting clothing or tuck in the loose ends to prevent them from catching in the machine.



① ②

FIGURE 62.—Jig saw.

46. Jig saw.—*a. Construction.*—The jig saw (fig. 62) differs radically in construction from the band scroll saw although the type of work for which it is intended is very similar. The jig saw, however, is more adaptable for cutting small, sharp curves because much smaller and finer blades may be used. Inside cutting also is better accomplished on the jig saw since the blade is easily removed and

inserted through an entrance hole bored in the stock. The jig saw consists mainly of a base or frame, driving mechanism, table, tension mechanism, guides, and saw blade.

(1) The frame consists of a substantial base which houses the driving mechanism, and a "gooseneck" or overhead framework to support the blade straining device. The size or capacity of a jig saw is determined by the distance between the blade and the gooseneck at table height. Some machines are designed with the overhead straining device suspended from above, independent of the base. Extra large stock can be worked on this machine.

(2) The driving mechanism is designed to produce a reciprocating, up-and-down movement of the saw blade. It is either directly coupled to the shaft of the motor or belt-driven through multiple step or cone pulleys. Several speeds are thus possible for different types of work. The upper end of the driving mechanism slides on machined ways and is fitted with a hook or clamp for holding the various saw blades, files, etc., used with the machine.

(3) The table is similar in construction to that of the band saw table. It may be tilted through a range of 90° (45° each way) and clamped in position. The throat piece is removable to provide extra space for changing blades or using various accessories.

(4) The blade straining mechanism maintains proper tension on the blade. The mechanism may be adjusted vertically to regulate the tension on the blades and to accommodate various blades of different length.

(5) Guides for the blade are located both above and below the table. The upper guide is adjustable vertically and may be positioned directly above the work, thus affording maximum control over the blade. The blade should not rub on the guides except when cutting. Rubbing tends to crystallize the steel, causing the blade to break easily. Some machines are equipped with a hold-down device or foot on the upper guide to prevent the blade from lifting the work on the upward stroke.

(6) Jig saw blades vary considerably in size and number of teeth per inch. Size is usually designated in thousandths of an inch. As a general rule, the softer the material, the larger should be the teeth. A blade with about 10 teeth per inch should be used to cut softwood. Hardwood requires a finer blade. Sanding and filing can also be accomplished on this machine by use of special attachments.

b. Operation.—(1) The jig saw is both simple and safe to operate. Only a few simple adjustments are necessary. Fasten the blade securely in the vises with the teeth pointing down and a slight tension

on the upper end. Adjust the guides so they touch the blade very lightly and position the hold-down foot directly on the upper surface of the stock. The hold-down foot is especially useful when cutting thin wood.

(*a*) *Inside scroll sawing.*—Mark the outline on the stock clearly with a smooth line following methods explained under band sawing. Bore a small hole ($\frac{3}{16}$-inch) in the waste stock near the outline for inserting the blade, thus gaining entry without cutting through the outline. Make the necessary adjustments and saw the inside outline. Saw the outside design last, following the procedure employed in band sawing; that is, saw the large curves first and then finish the smaller ones. Several pieces of the same design can be cut simultaneously by fastening them together. In this case be sure the table is square with the blade, otherwise the lower pieces will have a different size and shape.

(*b*) *Saber sawing.*—Saber sawing is accomplished with a short, stiff blade fastened in the lower vises of the machine only. The straining device is not required and may be removed for accommodating extra large stock. Also, since the upper end is free, stock can be easily slipped over the blade for inside sawing.

(2) The jig saw is a relatively safe machine to operate and no special safety precautions are given.

47. Jointer.—*a. Construction.*—The jointer or hand planer (fig. 63) consists essentially of a frame, cutter head, tables, fence, and guard.

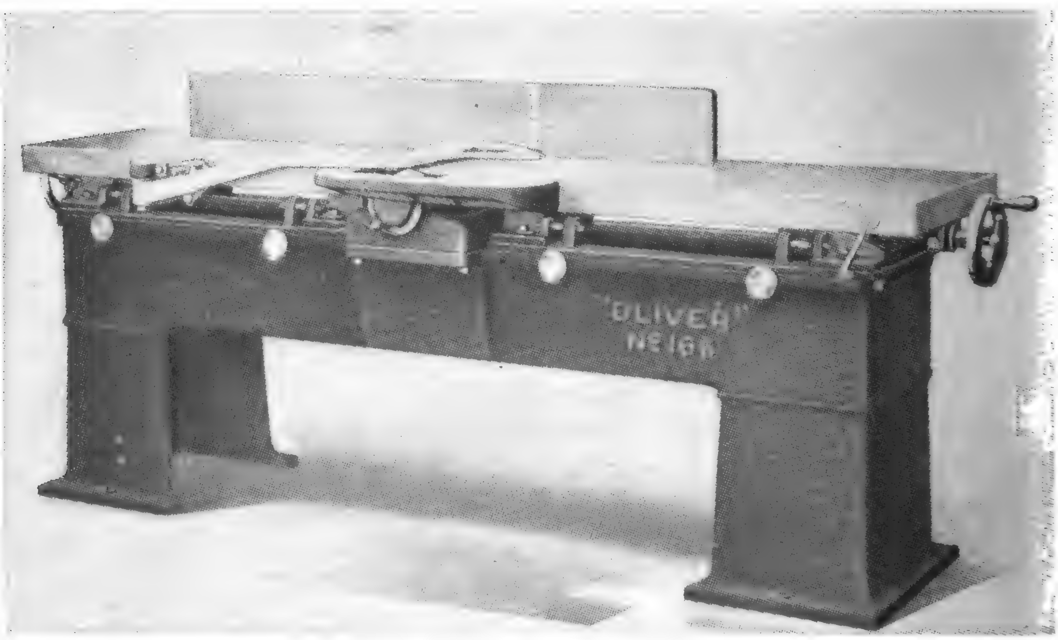


FIGURE 63.—Jointer.

(1) The frame of the floor type jointer is usually designed to provide toe room as it is important that the operator stand close to the machine when performing the various jointer operations.

(2) The cylindrical type cutterhead (fig. 64) is most generally used at present, having replaced the more dangerous type square head. The knives (generally three in number) are of high-speed steel, with a perfectly straight cutting edge. Each knife is accurately set in the cutter head and securely held in place by a chip breaker wedge and heavy flush type screws in order to prevent any possible change in adjustment during operation. The speed of the cutter head varies with the type of drive. Belt driven cutter heads usually run at speeds ranging from 4,500 to 6,000 rpm. The direct-driven type (see fig. 64) runs at the speed of the motor which is usually 3,600 rpm.

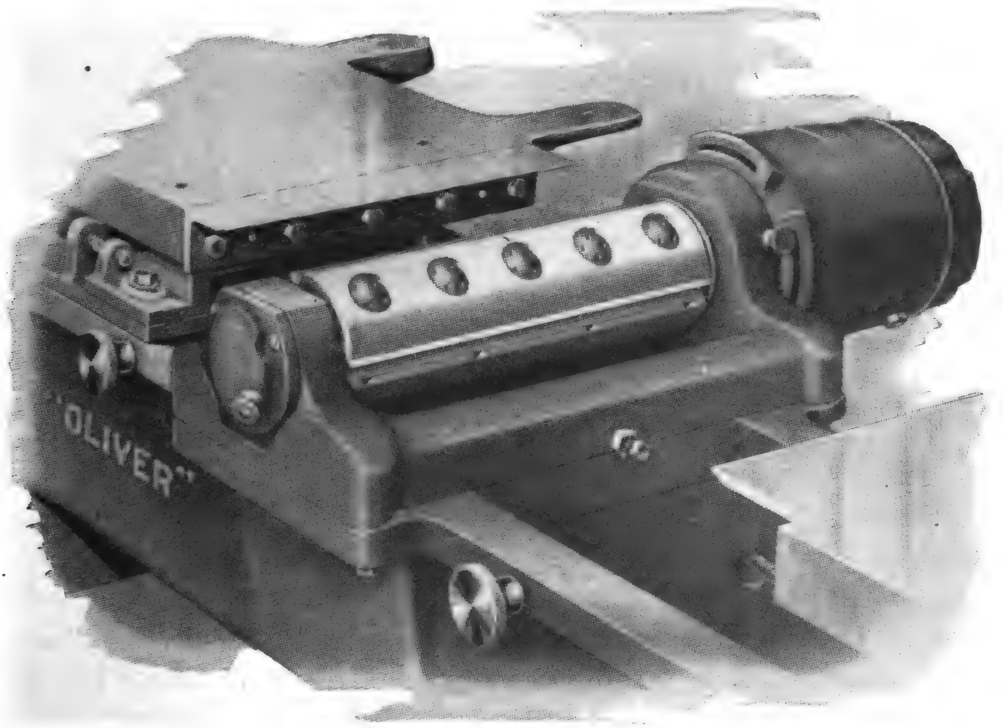


FIGURE 64.—Jointer cutter head.

(3) The tables (referred to as front or infeed table and back or outfeed table) are mounted on machined inclined ways. Each may be raised and lowered independently of the other, providing for individual adjustment. The infeed table supports the stock to be planed and is raised or lowered to regulate the depth of cut. The outfeed table supports the stock after it is planed and, except for special operations, is always set with its upper surface even with the highest point of revolution of the knives. The auxiliary ledge or table attached

to the infeed table (see fig. 63) provides additional support for wide stock when rabbeting. Both tables may be slid away from the cutter head to provide greater accessibility when desired.

(4) The fence serves to guide the stock across the knives at the desired place or angle. The fence may be tilted up to 45° and also positioned at any point across the tables.

(5) The most common type of guard is simply a metal or wooden plate covering the cutter head and hinged so that it may be pushed aside by stock passing over the cutter head. A coil spring acts to hold the guard in place and to cover as much of the cutter head as is not used.

b. Operation.—(1) The jointer is a very dangerous machine to operate. Therefore, strict attention should be paid to proper procedure and safety rules.

(*a*) *Adjusting tables.*—The depth of cut is regulated by raising and lowering the infeed table. There is consequently no definite setting for this table. The outfeed table, however, must be accurately set even with the top of the knives at their highest point of revolution. If the outfeed table is too low, the knives will cut slightly deeper the last inch or two of the board. This condition is evident by the fact that the stock drops slightly upon leaving the infeed table. If the outfeed table is too high, a slight bump or jar will be felt as the stock starts over it and more material will be removed at the beginning of the cut than at the end. If adjustment is necessary, lower the table until it is obviously too low. Start the machine and run a piece of scrap stock part way across the knives. Then stop the machine and bring the table up to the cut edge.

(*b*) *Edge planing.*—Set the fence at right angles to the tables. Examine the stock being planed to determine the direction of the grain and the straightest surface. Hold the straight side against the fence and take a light cut with the grain (fig. 65). Feed the stock slowly to avoid ripples in the planed surface. If the edge is hollow or concave, take several cuts on each end to partially straighten board before planing the entire length. Likewise, take several cuts in the middle of a board having a convex edge.

(*c*) *Face planing.*—Face planing refers to planing the wider sides or surfaces of stock. It is important to plane with the grain of the wood as in edge planing, and to take light cuts, depending on the width and hardness of the stock. Short pieces are difficult to control and are more safely handled with the aid of a push block (fig. 66). The push block should be used whenever possible, even on long pieces. Thin stock has a tendency to chatter, causing a ripply surface unless

backed up by a piece of heavier material. The piece used for this purpose is prepared as shown (fig. 67) so as to push the thin piece as well as hold it down.

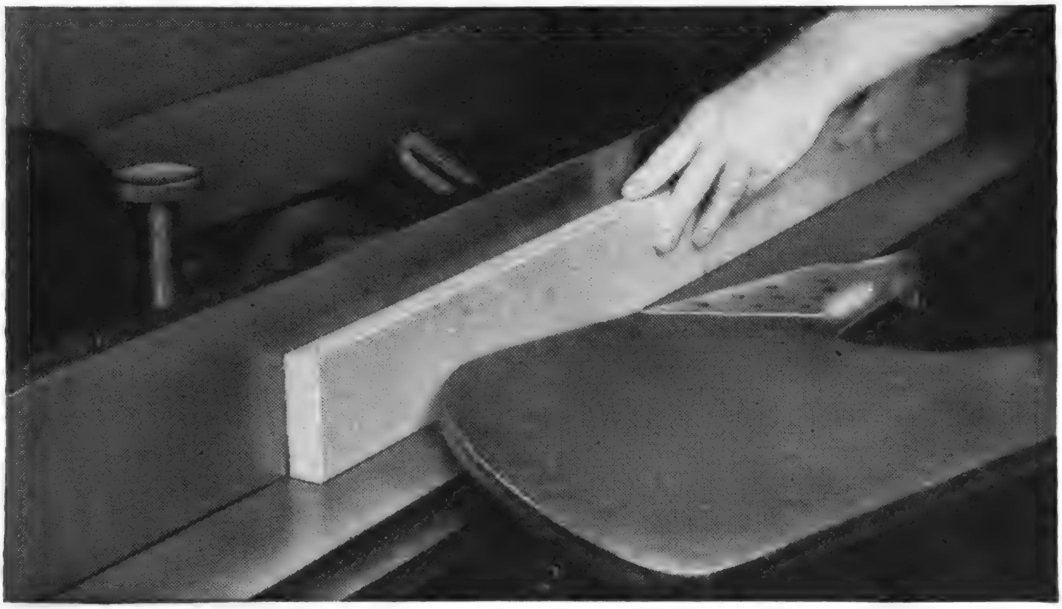


FIGURE 65.—Edge planing on jointer.

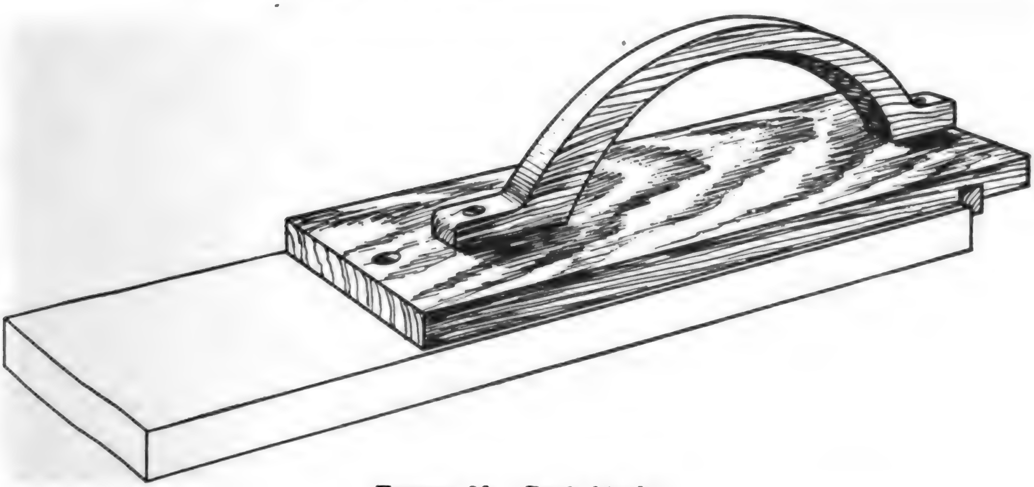


FIGURE 66.—Push block.

FIGURE 67.—Block for planing thin stock.

(*d*) *Squaring.*—Squaring usually refers to planing one edge at right angles to a face. The fence is set at right angles to the table and checked for accuracy with a square. One face is planed and then held tightly against the fence to plane an edge at right angles to it. Care must be exercised to hold the planed face against the fence.

(*e*) *Tapering.*—Tapering is accomplished by starting the piece on the outfeed table (see fig. 68) and continuing the cut in the usual manner. The depth of cut will gradually increase until the full

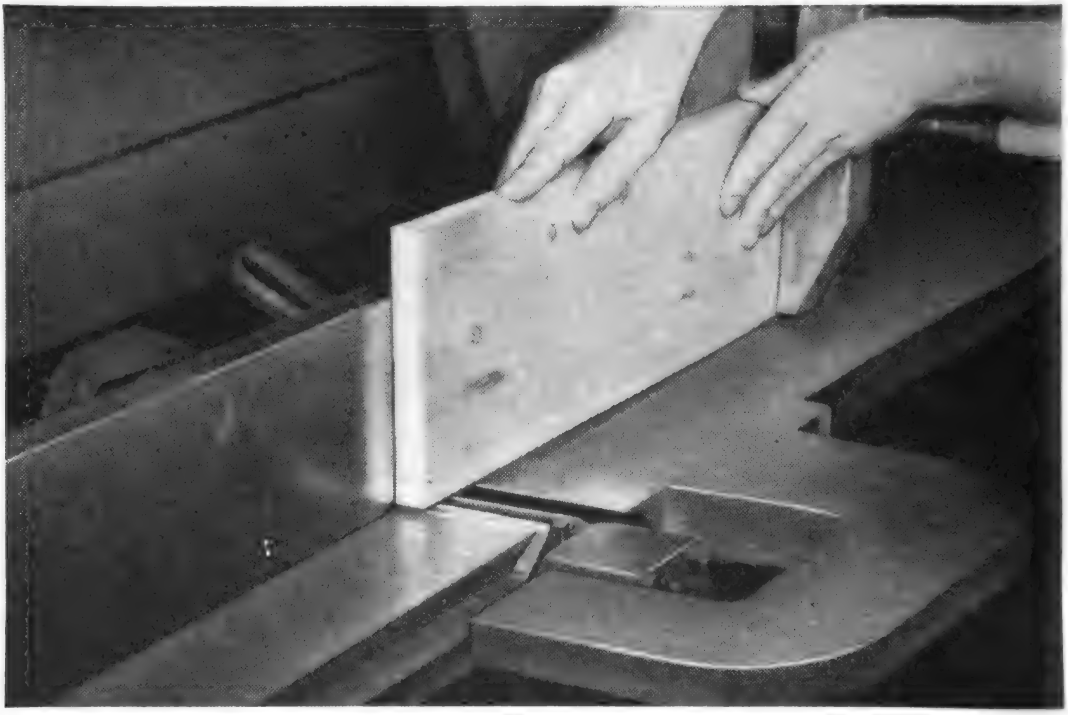


FIGURE 68.—Tapering on a jointer.

depth is reached as the end passes the cutter head. This same procedure is followed when it is desired to reduce the width or thickness of only one end of a board.

(*f*) *End planing.*—If the piece to be planed is cut to width, the piece is planed part way from one edge, turned around, and completed from the opposite edge (see fig. 69). This prevents splitting the rear edge of the piece as it passes over the cutter head. Boards not cut to exact width may be planed in one cut since some of the edge is to be removed in cutting to width. A light cut should be taken and the piece moved slowly across the knives to minimize the amount of splitting of the edge.

(*g*) *Rabbeting.*—Rabbeting is referred to as cutting a rectangular recess in the edge of a board (fig. 70). The fence is used as a guide to determine the width of the rabbet. If the rabbet is not too wide, the infeed table is set to the depth of rabbet desired and only one cut made. However, on very wide rabbets it is better to make several cuts, setting the table to the depth of rabbet desired for the final cut.

FIGURE 69.—End planing on jointer.

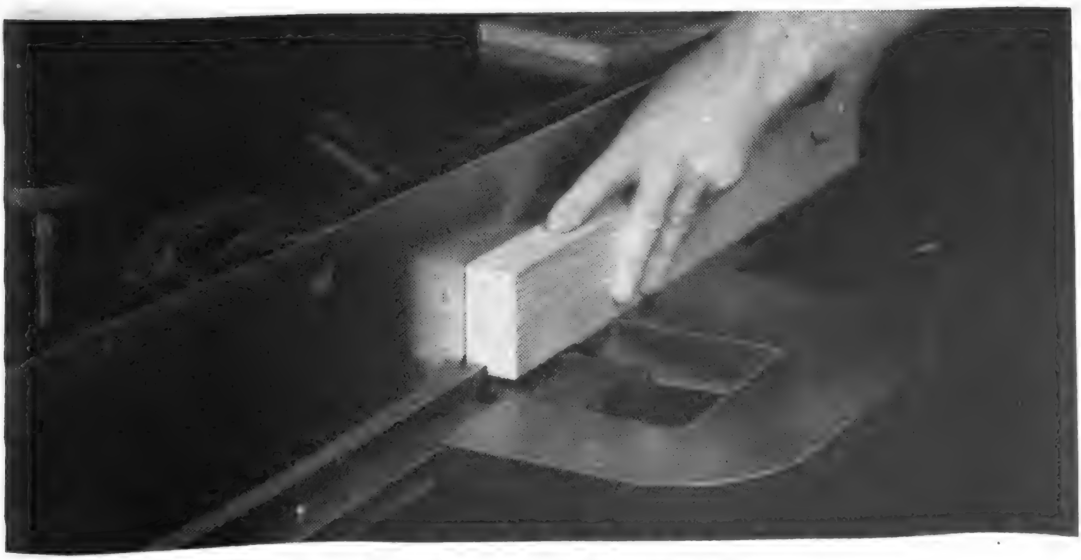


FIGURE 70.—Cutting a rabbet.

(*h*) *Beveling.*—Cutting an edge at an angle with the face of a board is referred to as beveling (fig. 71). If the full edge is not beveled, but simply the corner planed, it is referred to as a chamfer. When a chamfer does not extend the full length or width of the board, it is called a stop chamfer. These operations are performed with the fence tilted to the desired angle of the bevel or chamfer. If the angle is given in degrees, the fence is set by means of the graduated sector. If the angle is not known, the setting may be obtained by copying the angle with a sliding T-bevel and setting the fence accordingly. After the fence is adjusted, proceed as in ordinary edge planing. When chamfering, it is best to lower the infeed table for the full depth of the chamfer and make only one cut. Stop chamfers are produced by lowering both tables the same amount and clamping stop blocks on the fence to govern the length of the chamfer.

FIGURE 71.—Beveling on the jointer.

(2) The following safety precautions should be carefully observed:

(*a*) Do not use machine with dull knives. Dull knives may cause a kick-back which can lead to serious injury.

(*b*) Always stop the machine before removing shavings or adjusting the fence.

(*c*) Use guard whenever possible.

(*d*) Keep hands a safe distance from the ends of the board; a sudden jar or kick-back may cause the hands to drop into the knives.

(*e*) Take a light cut, especially on wide stock, to avoid a kick-back.

(*f*) Use a pusher, particularly on small, short pieces, to prevent injury to the hands.

48. Planer or surfacer.—*a. Construction.*—The surfacer (fig. 72) is used mainly for finishing surfaces of flat stock and reducing stock to thickness. The more common type planes one surface at a time and is referred to as a single surfacer. Size refers to maximum width and thickness of stock accommodated. The machine illustrated will take stock up to 24 inches wide and 8 inches thick. The 24- and 30-inch single surfacers are most commonly used in the general wood shop. The essential parts include the frame, table or bed, feed rolls, cutter head, chip breaker, and pressure bar.

FIGURE 72.—Single surfacer.

(1) The frame is generally a heavy one-piece casting having wide floor flanges to give it stability and firm support.

(2) The table or bed is mounted on machined ways and is raised and lowered by an accurate adjusting mechanism. The vertical travel

of the table determines the maximum thickness of stock accommodated. This is generally 6 inches on smaller machines and 8 inches on the larger types. A scale and pointer conveniently located indicate the thickness of stock after planing.

(3) Single surfacers are generally equipped with one pair of infeed and one pair of outfeed rolls. The infeed rolls, located in front of the cutter head, take hold of the stock and push it past the knives; the outfeed rolls deliver the planed stock from the machine. The upper infeed roll is of sectional construction (fig. 73), affording a certain amount of flexibility. Each section is mounted on springs which allow it to yield as much as $\frac{5}{16}$ inch, thus permitting the roll as a whole to adjust itself to slight irregularities on the surface of the stock being worked. Pressure is applied to the upper feed rolls by heavy coil springs, which also afford additional vertical adjustment to compensate for variations in thickness of stock. Power is supplied to the upper rolls only on small machines, while all rolls on large machines are power driven. Feed speeds vary from 10 to 150 feet per minute. Standard feeds available on most machines are 20, 30, 40, and 60 feet per minute.

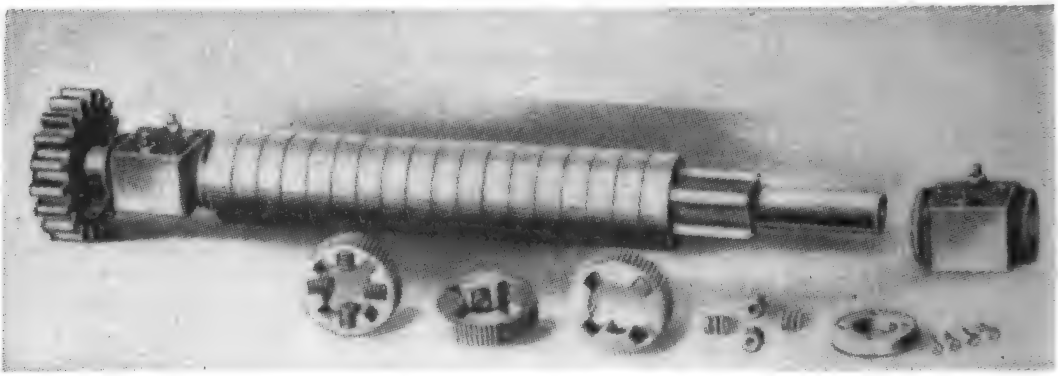


FIGURE 73.—Sectional infeed roll.

(4) The chip breaker rides on the stock directly in front of the cutter head. It holds the work down against the table and breaks the chips off short, preventing the wood from splintering out and producing a rough surface. The chip breaker also is of sectional construction (fig. 74), permitting it to ride over surface irregularities.

(5) The pressure bar is of solid construction. It is located back of the cutter head and holds the work down against the table to prevent chattering.

(6) The cutter head or cylinder is very similar in construction to that of the hand planer or jointer. It is usually equipped with three,

four, or six knives according to size. The cutter head rotates against the movement of the stock through the machine. Motor on head types normally operates at 3,600 rpm. A knife grinding attachment is usually standard equipment. Cutter head knives can be ground accurately with this device without removing the cutter head or the knives from the machine. The location of the feed rolls, chip breaker, and pressure bar with respect to the cutter head is shown in figure 75.

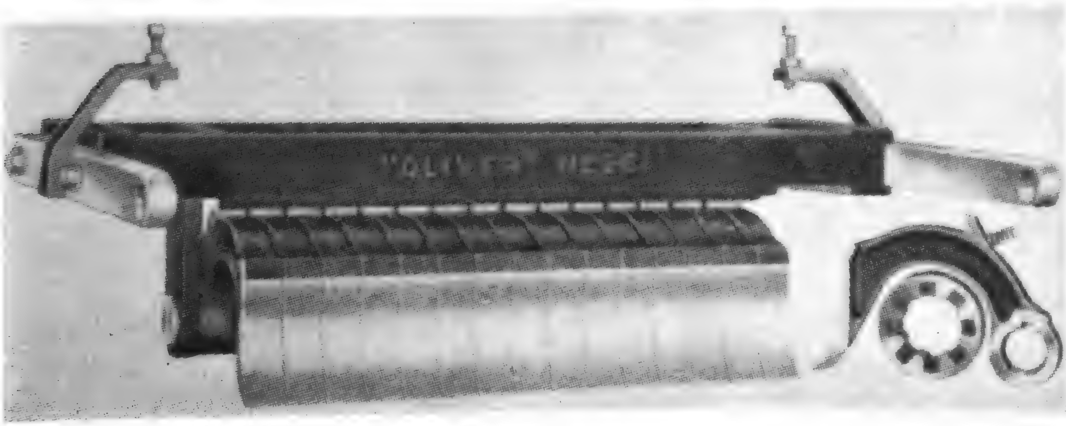


FIGURE 74.—Chip breaker.

b. Operation.—Set the surfacer bed for a thickness 1/16 inch less than the maximum thickness of the stock to be planed. If the stock is warped or twisted, one surface should be straightened on the jointer before starting it through the surfacer. Push the stock between the infeed rolls, with the flat surface down against the table and the grain running toward the front of the machine so that the knives will cut with the grain. Long stock should be supported at the outfeed end of the machine to avoid undue strain on the upper outfeed roll due to the weight of the piece. Stock too short to extend the full distance between the infeed and outfeed rolls is likely to be thrown violently from the machine. The minimum length of stock that can be safely handled varies with the type of surfacer. As a general rule, stock should be not less than 12 inches in length. When surfacing a number of short pieces to the same thickness, each piece should be butted against the preceding one to prevent a possible kick-back. Always stand to one side of the machine to avoid being struck, in event a piece is thrown from the machine.

49. Shaper.—*a. Construction.*—The shaper is used mainly in trimming, shaping, and molding stock irregular in outline. Various types are produced, a single spindle type being shown in figure 76. The shaper consists essentially of a spindle, spindle top, cutters and cutter heads, table, yoke, and base.

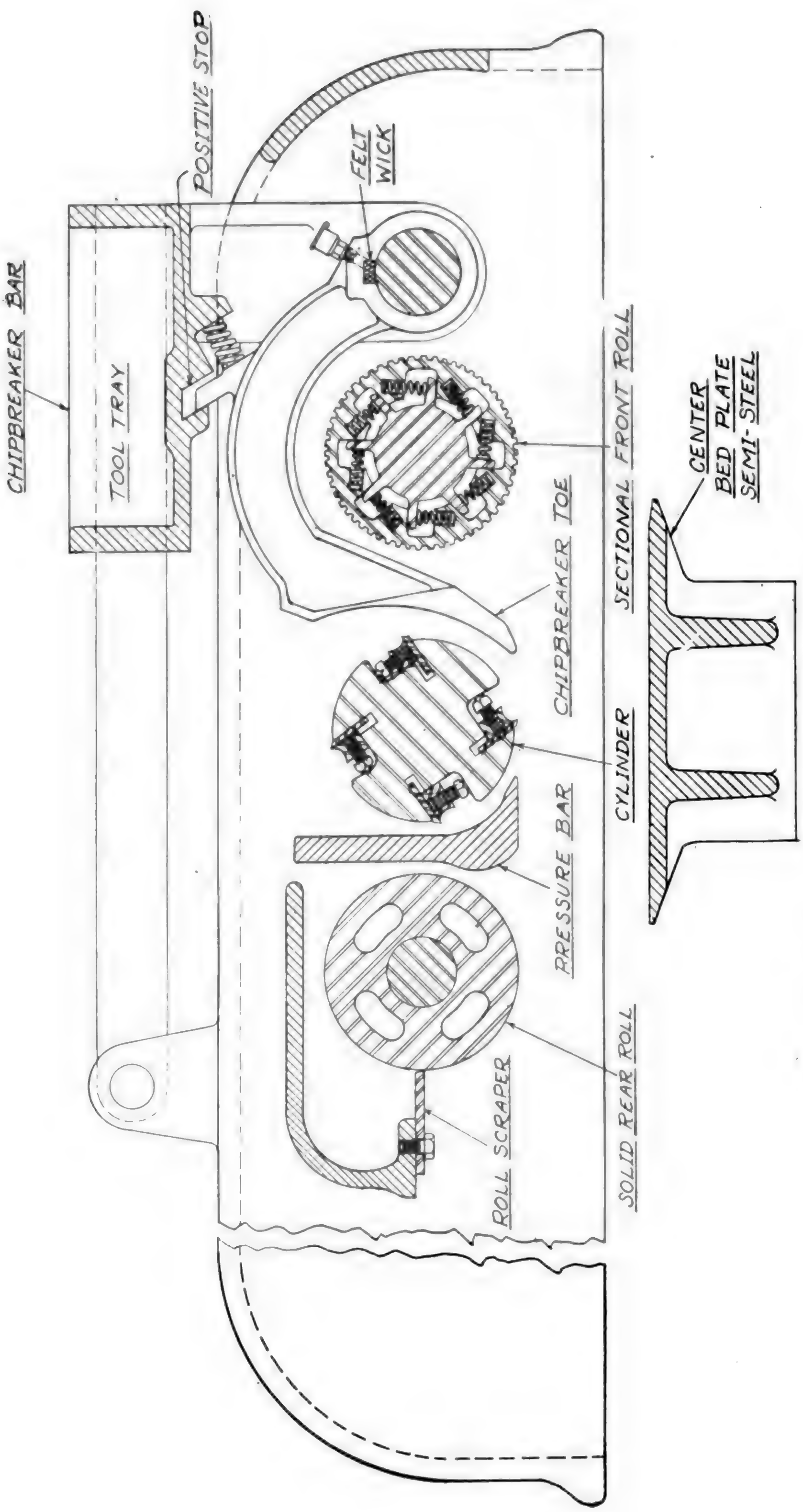


FIGURE 75.—Sectional view of planer head.

(1) The spindle rotates at a high rate of speed, generally 7,200 rpm. The direction of rotation is usually counterclockwise. Lower speed shapers, however, are generally equipped with a reversing device as a smooth cut is not ordinarily possible against the grain except at high speeds.

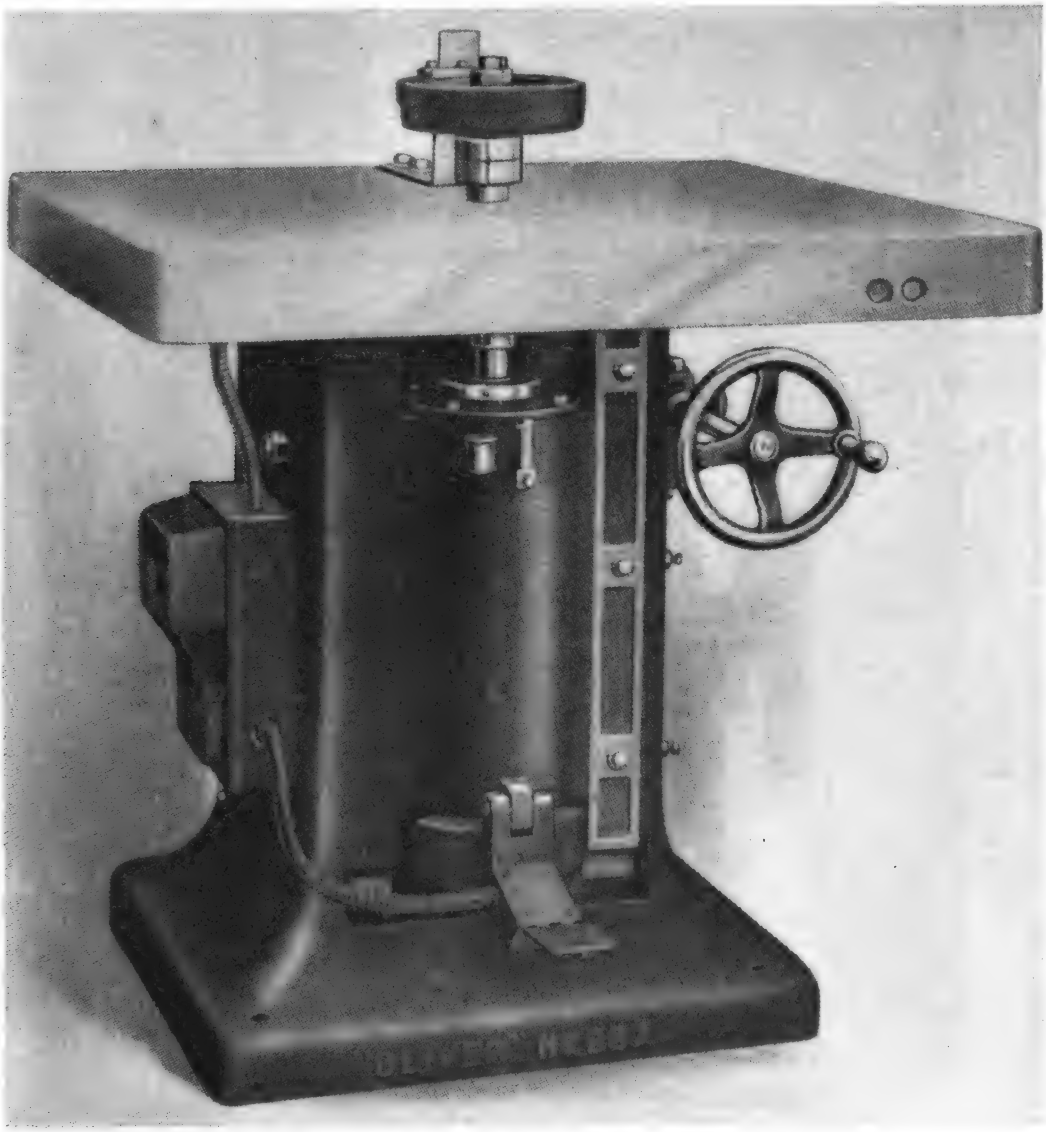


FIGURE 76.—Single spindle shaper.

(2) The spindle top (fig. 77) is screwed onto the spindle and provides a means for mounting cutter heads and knives. Various sizes are available ranging from 5/8 inch to 1 3/8 inches in diameter and 6 to 12 inches in length. Spindle top fittings include two knife collars and several spacing collars. Knife collars are grooved to retain cutting knives and are assembled as shown in figure 78. Spacing collars are placed above and below the knife collars to locate the knives

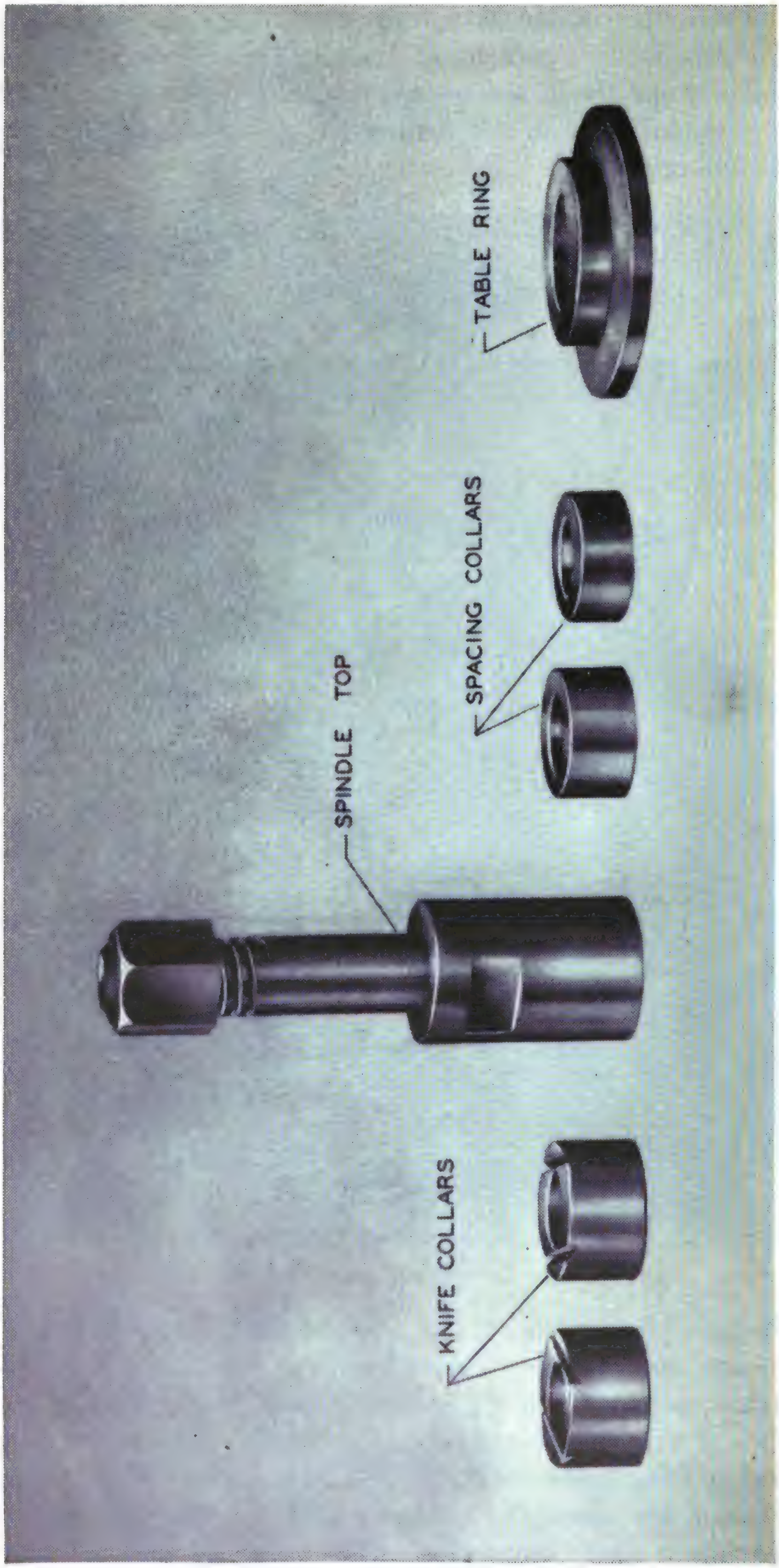


FIGURE 77.—Spindle top and fittings.

properly on the spindle top. When a long spindle top is used, additional support and stability are provided by an overhead or top bearing (fig. 79).

(3) The form of cutter most generally used on the standard shaper is the flat steel knife with the cutting edge ground to the desired shape of cut. Two are generally used together and assembled as

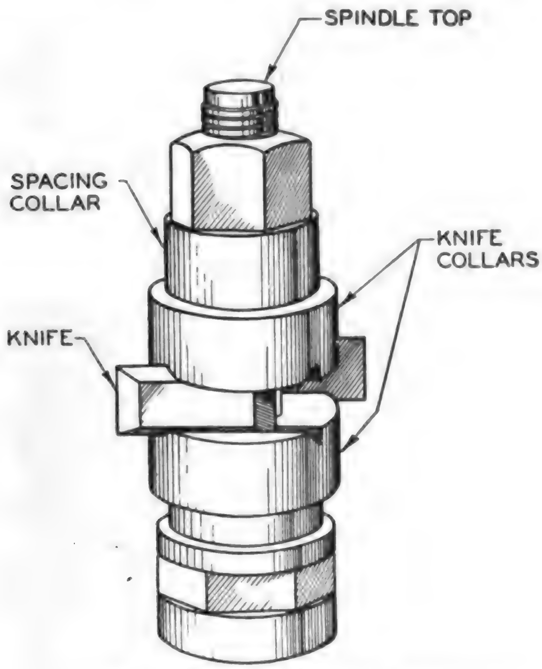


FIGURE 78.—Knife and collar assembly.

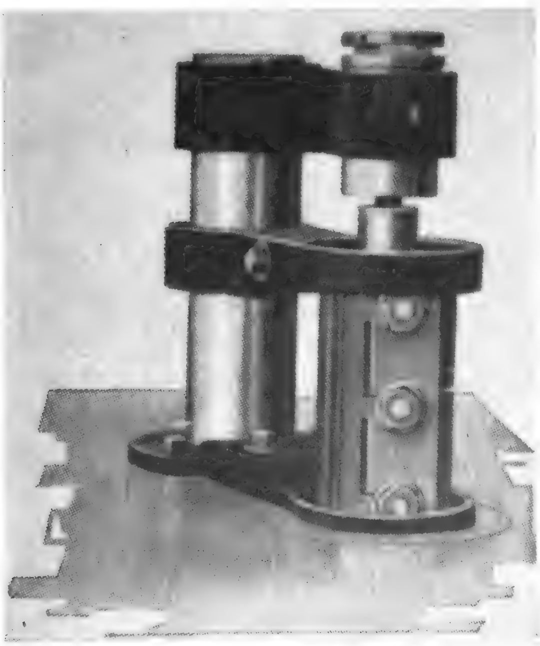
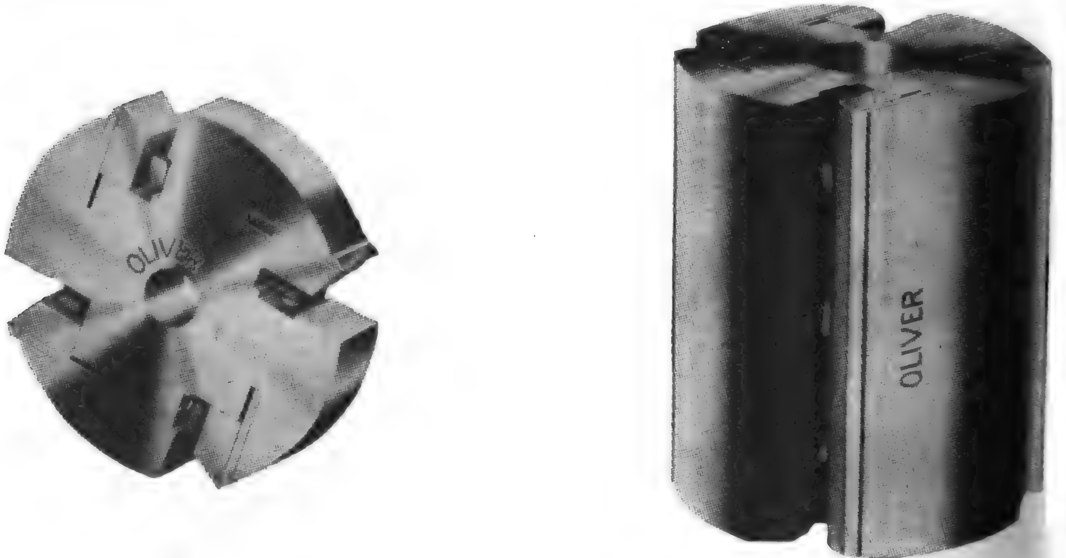


FIGURE 79.—Overhead bearing.

shown in figure 78. Solid cutters (milled to the desired shape) and cutter heads are also used. Two sizes of cutter heads are shown in figure 80.

(4) The table is attached to the base in a fixed position. The opening for the spindle (throat) is fitted with a plate generally made up of two or more concentric rings each of which may be removed separately to obtain several different sizes of throat openings. A raised edge on one surface of these rings (see fig. 77) serves as a guide against which stock may be held when shaping.

(5) The yoke houses the spindle and provides support for the motor. It may be raised and lowered by means of an accurate adjusting mechanism in order to position the cutters above the table as desired.



① ②

FIGURE 80.—Shaper cutter heads.

(6) The base or frame is of heavy construction to provide stability and absorb vibration due to the high speed of the spindle.

b. Operation.—(1) The shaper is one of the most dangerous woodworking machines to operate. Particular care should be exercised at all times and particular attention paid to safety rules.

(*a*) *Setting knives.*—Flat steel knives are most generally used on the standard shaper. When securing knives between the knife collars, it is very important that both be exactly the same width. If knives of unequal width are used, less gripping force will be exerted on the narrower one with the result that it is likely to work out of adjustment or be thrown from the machine. To determine whether knives are of equal width, make the following test: Insert knives be-

tween the grooved collars and turn down retaining nut lightly by hand. Take hold of the knives (one in each hand) and pull outward. Both should slide with equal ease, otherwise the knives are of unequal width and should not be used together. The depth of cut is determined by the distance the knives project from the collars. It is important that both knives project exactly the same distance. After the proper setting is obtained, tighten the nut securely.

(*b*) *Guiding stock.*—The shaper collars only are used as a guide when shaping stock to curved outlines. However, part of the original square outline must remain to bear against the collar. If the full edge were cut away, no definite control could be exercised over the depth of cut and the outline could not be followed. When a number of pieces are to be cut to the same outline, a template is used as a guide. This is referred to as shaping to template (see fig. 81).

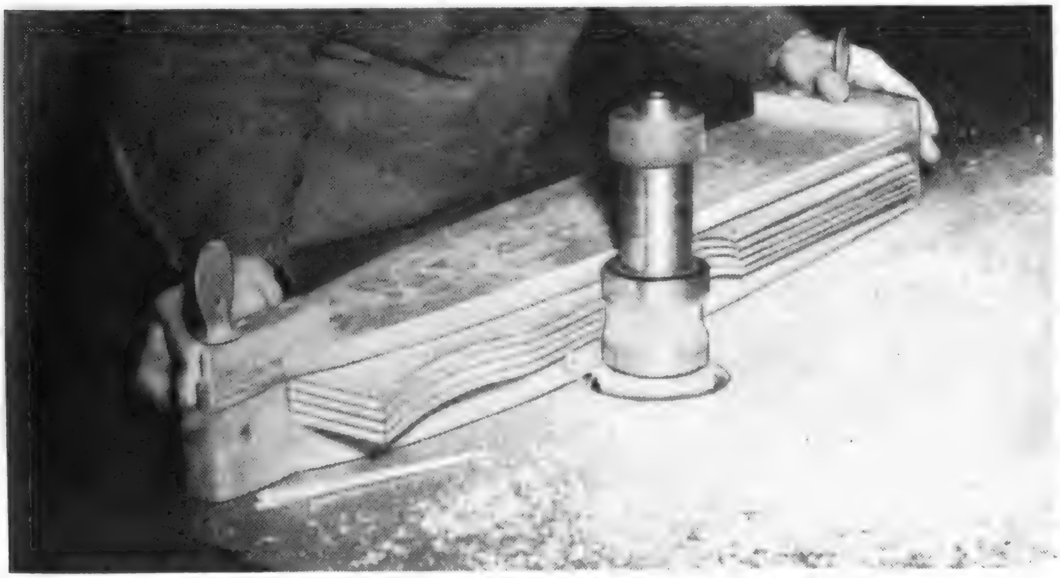


FIGURE 81.—Shaping to template.

The stock is clamped to the template which is accurately cut to the desired outline. The template bears against the shaper collar, regulating the depth of cut and duplicating the outline on the attached piece. Stock may be cut roughly to shape before attaching to the template, reducing the amount of stock to be removed by the shaper. The cutter head is used when shaping wide-edged stock or when shaping several pieces simultaneously.

(2) The following safety precautions should be carefully observed:

(*a*) Be sure spindle revolves freely before turning on power.

(*b*) Clear table of all tools and materials.

(*c*) Check to be sure the spindle top and knives are correctly adjusted and fastened securely. If a cutter head is used, a thin piece of paper placed between the knives and cutter head will prevent the knives from slipping.

(*d*) Use guards and holding devices whenever possible.

(*e*) Check all bolts, screws, and clamps to guard against parts working loose due to the high speed of the machine.

50. Boring machine.—*a. Construction.*—The boring machine (fig. 82) is designed to hold and operate various wood bits. The single spindle manually operated borer is most adaptable for the general wood shop. It consists essentially of a frame or column, boring head, table, and various machine wood bits.

(1) The column is of heavy construction with machined ways cast into the frame for adjustable mounting of boring head and table.

(2) The table may be tilted up to 45° (indicated by pointer and sector) and rotated through a complete revolution. It is therefore possible to bore at any angle or combination of angles. Holes are suitably located in the table for mounting a fence and special guides and jigs. The arm supporting the table slides on machined ways. Two adjustable hold-down rods or fingers fitted into the column above the table serve to hold the work down on the table when withdrawing the bit.

(3) The boring head is mounted on carefully machined ways and adjusted to slide freely up and down. Vertical movement is controlled by the foot lever, leaving both hands free to control the work. Adjustable stops are provided which regulate the length of stroke of the boring head. The spindle and motor shaft are combined. Spindle speed is usually 3,600 rpm.

b. Operation.—(1) Care should be exercised in operating the boring machine to avoid injury from the rotating bit. Loose clothing, especially sleeves, is hazardous as it may become wrapped around the rotating bit. The work should be held firmly or clamped to the table to prevent the piece from twisting sharply in event the bit becomes jammed in the wood. Always stop the machine when making adjustments.

(2) When setting up the machine for boring, be sure the bit is securely tightened in the chuck. Otherwise the chuck is likely to rotate without turning the bit. Adjust the table vertically and set the adjustable stops to regulate the movement of the head according to the depth of hole desired. If the hole is to go through the stock, place a piece of flat scrap stock on the table for the bit to cut into, assuring a clean hole and preventing damage to the bit. Position

the work directly under the bit and adjust the hold-down rods to prevent the work from lifting when the bit is withdrawn. Hold the work securely when boring.

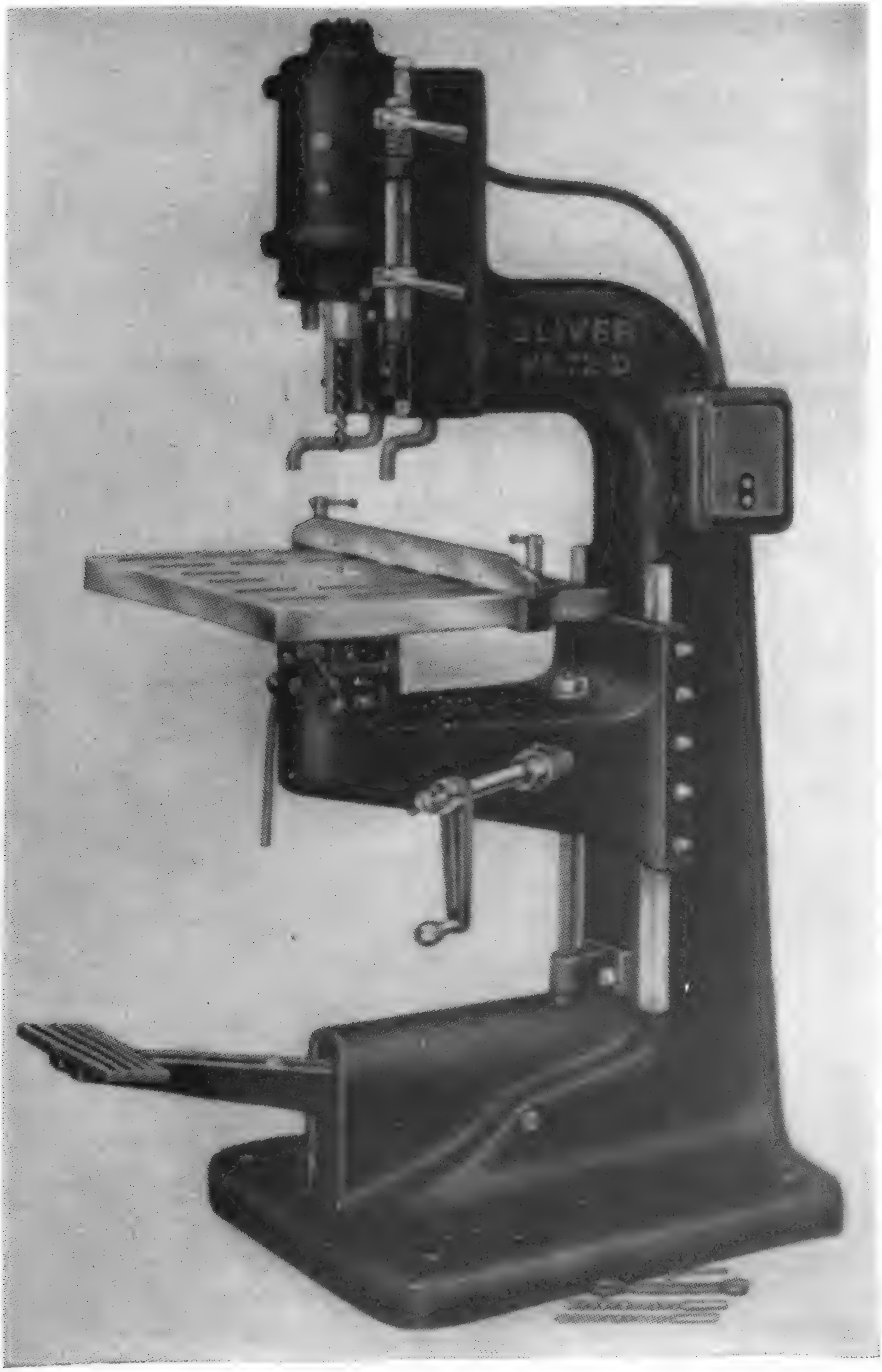


FIGURE 82.—Wood-boring machine.

51. Combination disk and spindle sander.—*a. Construction.*—The combination disk and spindle sander (fig. 83) is adaptable to the majority of sanding operations and is the type generally used in the wood shop.

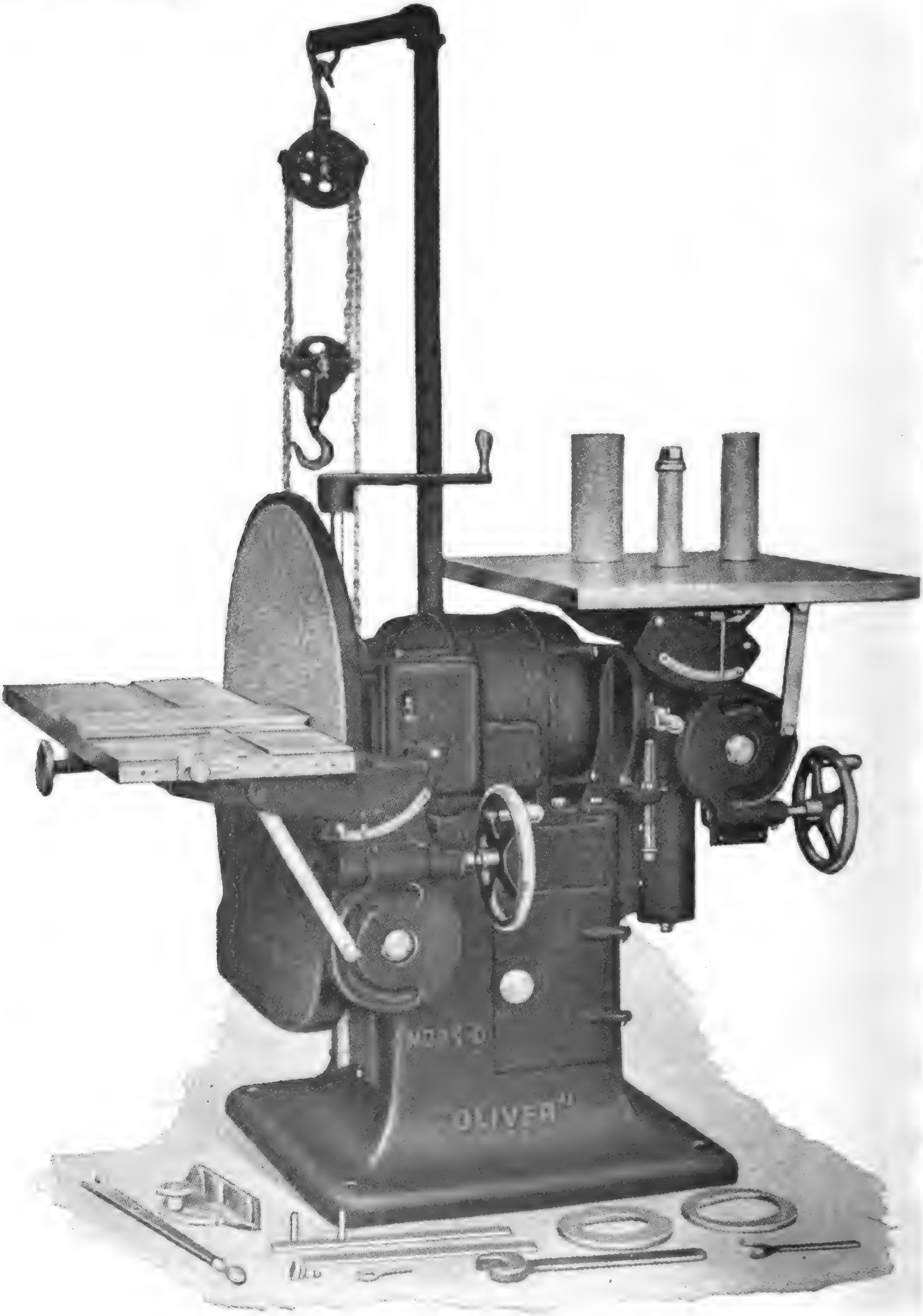


FIGURE 83.—Disk and spindle sander.

(1) The disk is machined and balanced to run perfectly true. Abrasive action is provided by garnet or sanding paper cemented to the face of the disk. The standard size disk is 30 inches in diameter; other sizes, however, are also available.

(2) The disk table is mounted on machined ways, providing for vertical adjustment. The table may also be tilted upward 10° and downward 45°. Machined grooves in the table accommodate a miter gage for accurate mitering, squaring, and sanding stock to width.

(3) The spindle table also may be tilted up to 10° one way and 45° the opposite way. Several throat plates are usually provided, each having a different size opening for accommodating various sizes of sanding drums.

(4) The spindle is driven through a clutch mechanism, providing control of the spindle independently of the disk. In addition to rotating, a reciprocating mechanism also moves the spindle up and down in order to distribute the sanding action over a greater portion of the sanding drum.

(5) Sanding drums are made of steel, rubber, or wood and are secured to the spindle by means of a hexagonal nut. Sandpaper or garnet paper is glued or cemented to the drum. Several sizes are available.

b. Operation.—(1) Operations such as squaring ends of stock, and sanding miters, compound miters, bevels, and chamfers may be performed on the disk sander using the miter gage in the table slot which is parallel to the disk.

(*a*) When squaring stock, both the miter gage and table are set at right angles with the disk. The edge of the stock is held against the miter gage and the end pressed against the disk. The stock should be moved back and forth across the face of the sanding disk in order to distribute the sanding action.

(*b*) A miter is sanded in a similar manner with the miter gage set at the angle of miter.

(*c*) A compound miter is sanded with both the miter gage and table set at the required angle with respect to the disk.

(*d*) Bevels and chamfers are sanded with the table set at the angle of chamfer or bevel.

(2) Stock may be sanded to uniform width by using the miter gage in the slot which is at right angles to the disk (fig. 84). The miter gage is actuated by means of a hand lever. The pieces to be sanded are held against the miter gage and pressed against the disk. An adjustable stop block attached to the table stops the movement of the handle and regulates the final width of the pieces.

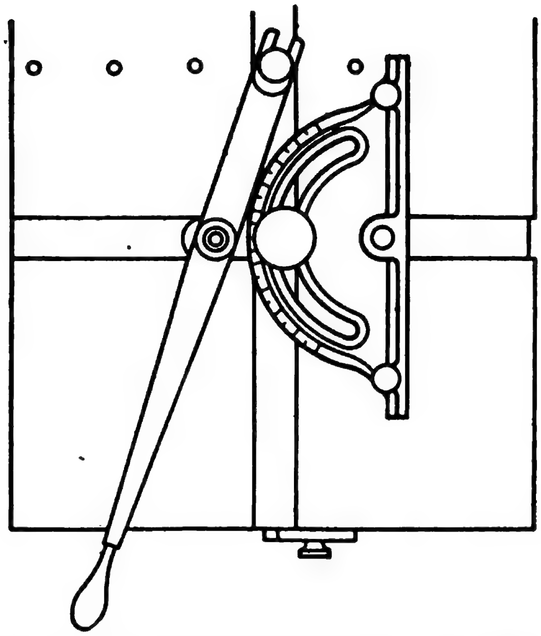


FIGURE 84.—Miter gage arranged for sanding to uniform width.

(3) Roughly sawed wooden disks may be sanded to a perfectly circular shape by using the circular sanding attachment (fig. 85). The steel pivot pin is first driven into the center of the wooden disk and then fitted into a hole in the steel plate which will bring the edge of the wooden disk as near as possible to the sanding disk. Final adjustment is accomplished by moving the table toward or away from the disk by means of a hand screw provided. The wooden disk is then slowly rotated by hand and all irregularities of outline removed. The operation is continued until the disk is circular and of the desired diameter.

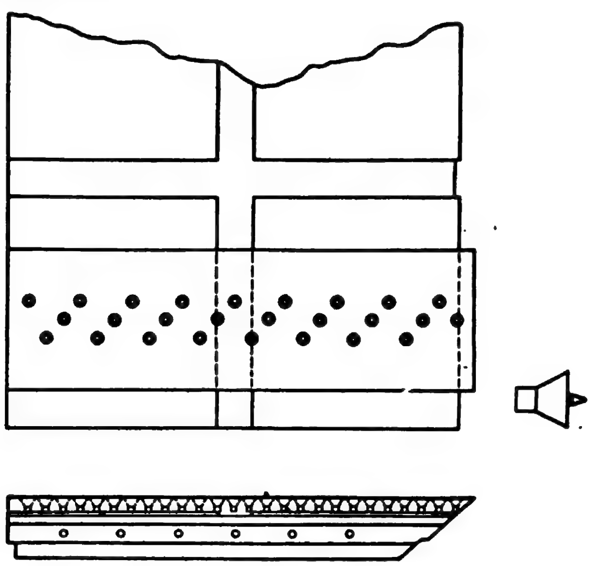


FIGURE 85.—Circular sanding attachment.

(4) The spindle sander is used for sanding and shaping inside curved outlines. Guides are not ordinarily used, the stock being guided freehand much as in shaping. The diameter drum to be used depends on the sharpness of the curves in the outline. As large a diameter drum as possible should be used to produce a smooth surface free from ripples.

52. Wood lathe.—*a.* The wood lathe is used for turning woodstock to shape. The motor headstock speed lathe (fig. 86) is most adaptable for general wood turning and consists mainly of the bed, headstock, tailstock, live and dead centers, tool rest, and tool rest holder.

(1) The bed is machined to provide accurate ways for supporting the headstock, tailstock, tool rest holder, etc.

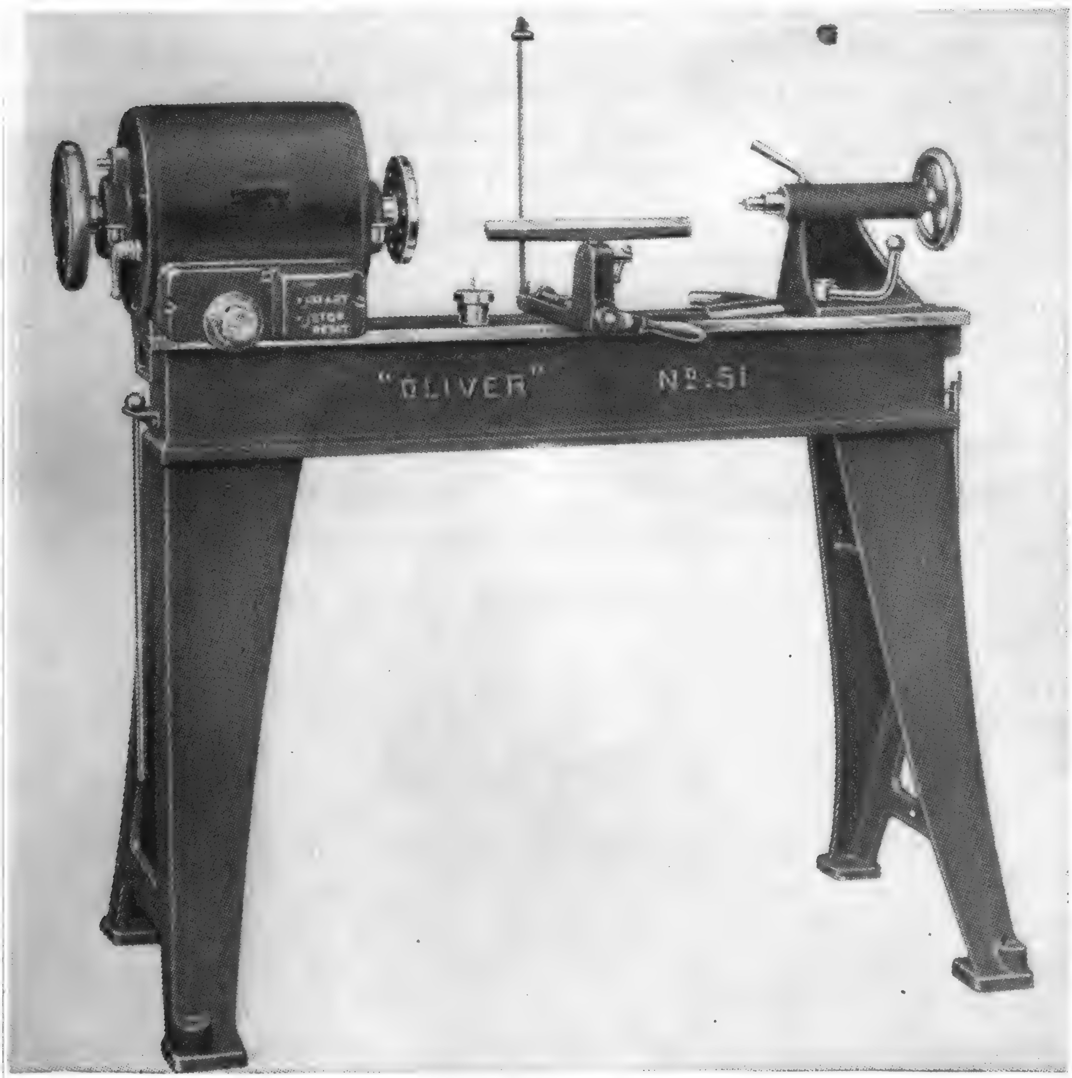
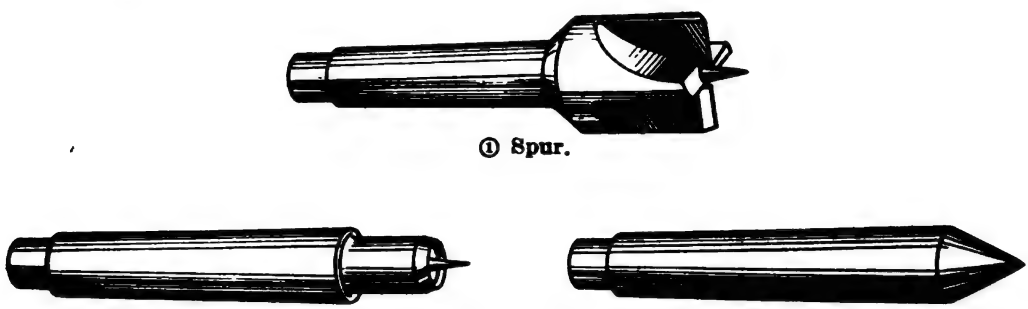


FIGURE 86.—Speed lathe.

(2) The motor, having a hollow shaft fitted out as a spindle, constitutes the headstock. The spindle is threaded on the inner end for attaching various faceplates and chucks; and also taper bored to receive a live center. The outer end is fitted with a handwheel which is also used as an end faceplate. Spindle speed is adjustable and ranges from 600 to 3,600 rpm.

(3) The tailstock may be located at any point along the bed and secured in position by means of a positive locking clamp. The spindle is bored to receive a No. 2 Morse taper dead center. The handwheel actuates a screw which moves the spindle in and out of the tailstock housing. Running the spindle in as far as it will go automatically ejects the dead center.

(4) The center used in the headstock is referred to as a live center (fig. 87①) since it rotates with the spindle. The tailstock center does not rotate and is referred to as a dead center (fig. 87② and ③). Centers are ground to the exact taper of the holes in the headstock and tailstock spindles. Friction between the tapered metal surfaces is sufficient to prevent the centers from turning in the spindle.



① Spur.

② Cup. FIGURE 87.—Lathe centers. ③ Cone.

(5) The tool rest is clamped in the tool rest holder and used to support the turning tools. The tool rest holder may be securely locked at any point along the lathe bed, and also adjusted so that the tool rest will be as near the work as desired. Several sizes of tool rests are used, depending on the length and outline of the work being turned.

b. Shaping stock in the wood lathe is principally a hand operation involving the use of various wood chisels, gouges, and other special cutting tools. Stock is mounted either between centers, or on a faceplate attached to the headstock. Usually, long stock is mounted between centers. Short stock, wooden disks, etc., are mounted on the headstock only, using some form of faceplate. Shaping is accomplished by holding one of the various turning tools against the stock s it is rotated by the headstock.

Section VII

CONSTRUCTION AND REPAIR OF WOODEN AIRCRAFT

53. Nomenclature.—Figures 88 and 89 identify and show the interrelation of various structural members of a wooden aircraft for reference in the discussion contained in this section dealing with the construction and repair of such parts.

54. Bending wood.—*a. General.*—Curved wooden parts of an airplane may be either steamed and bent to shape, or laminated and bent without steaming or other preparation. In either case the grain follows the curvature of the part, making it more serviceable and less subject to splitting and breaking than a part cut to shape. In order to obtain maximum strength in any curved member, the wood used must be straight-grained and free from defects.

b. Steam bending.—(1) Steam bending should be employed in aircraft work for bends of minor severity. When wood is bent, the fibers on the convex side of the bend are in tension and will stretch only slightly before tension failure occurs. Wood on the concave side is in compression, and when properly softened some woods can be compressed considerably without detriment.

(2) No general rule may be laid down as to the best degree of seasoning preparatory to steaming, either from the standpoint of the bending operation itself or the strength of the finished part. However, when the curvature is not severe, parts of adequate strength may be formed from stock which has been air-dried to a moisture content of 12 to 15 percent. After seasoning and just before steaming, the wood should be surfaced, or smoothly sawed to dimensions only sufficiently greater than final size to provide for shrinkage and finishing.

(3) One form of tank used for steaming wood in preparation for bending is shown in figure 90. Steaming permanently reduces the strength of wood due to the high temperature involved and the higher the temperature, the greater the weakening effect. For this reason high temperature steam (temperatures above 212° F.) should not be used. Furthermore, steaming should not be continued longer than 1 hour for each inch of thickness.

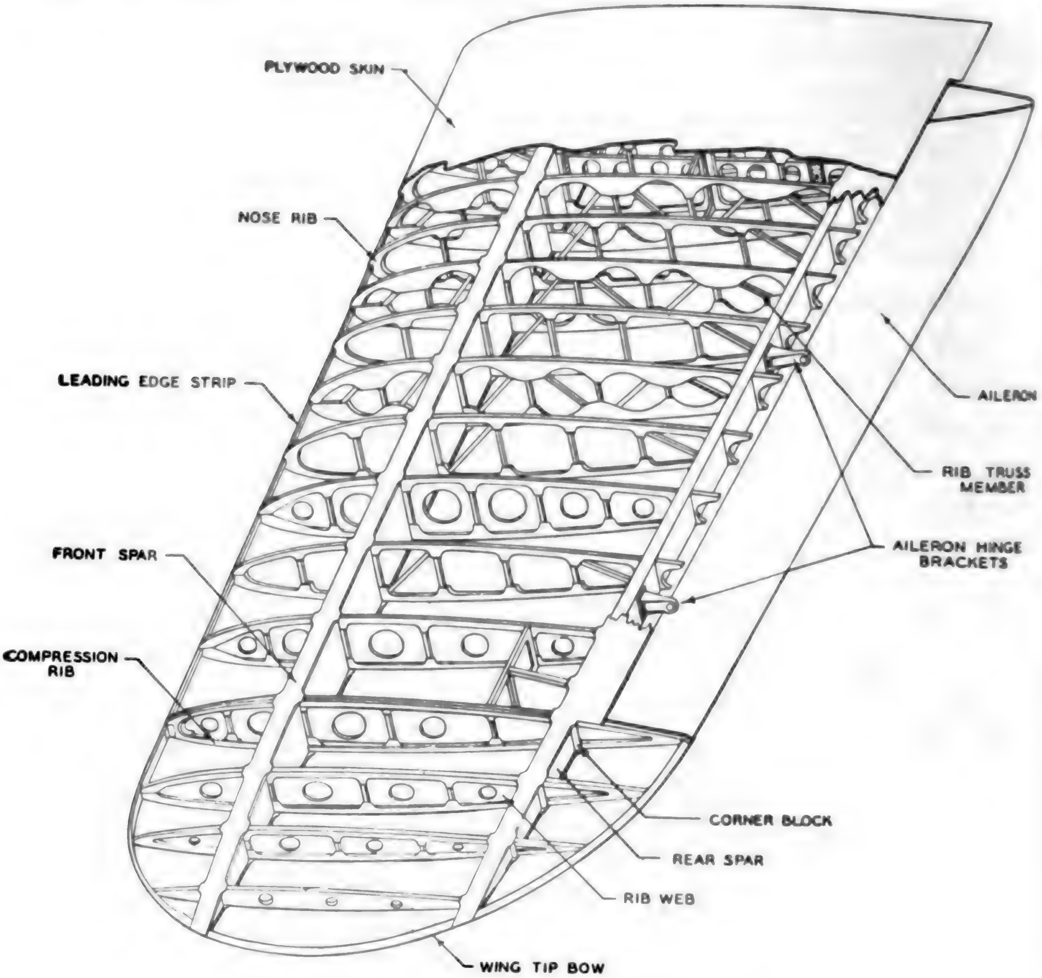


FIGURE 88.—Wooden wing construction.

(4) Bending is accomplished immediately after the wood has been properly steamed. Where the curvature is not severe, bending may be accomplished by hand, as in bending cap strips over a form (fig. 91). If, however, bending involves severe deformation, it is necessary that most of the deformation be forced to take place as compression or shortening. This may be accomplished by means of a forming die and holding strap (fig. 92① and ②). The stock to be bent is snugly fitted between the bulkheads as shown and the assembly is

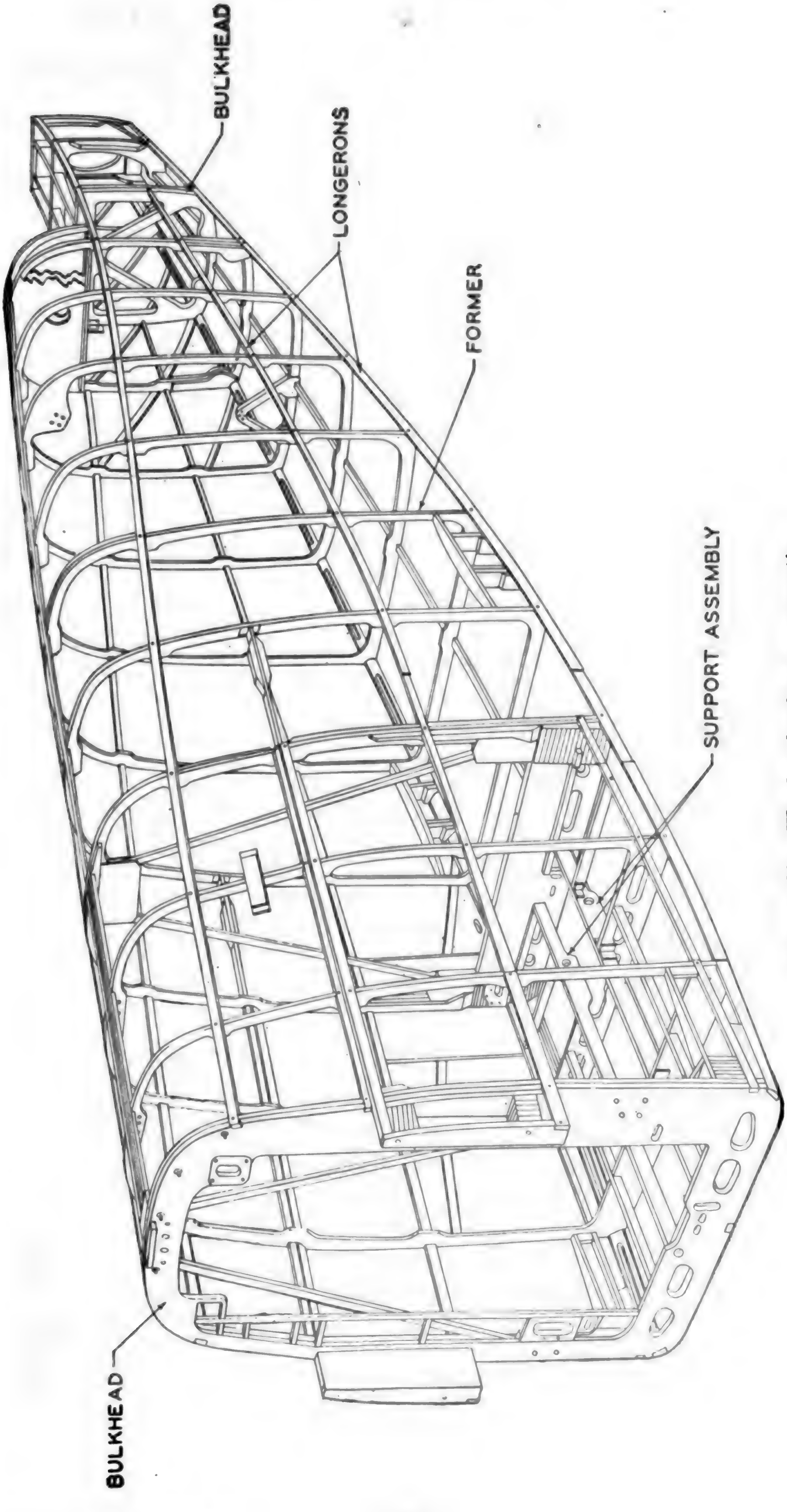


FIGURE 89.—Wooden fuselage construction.

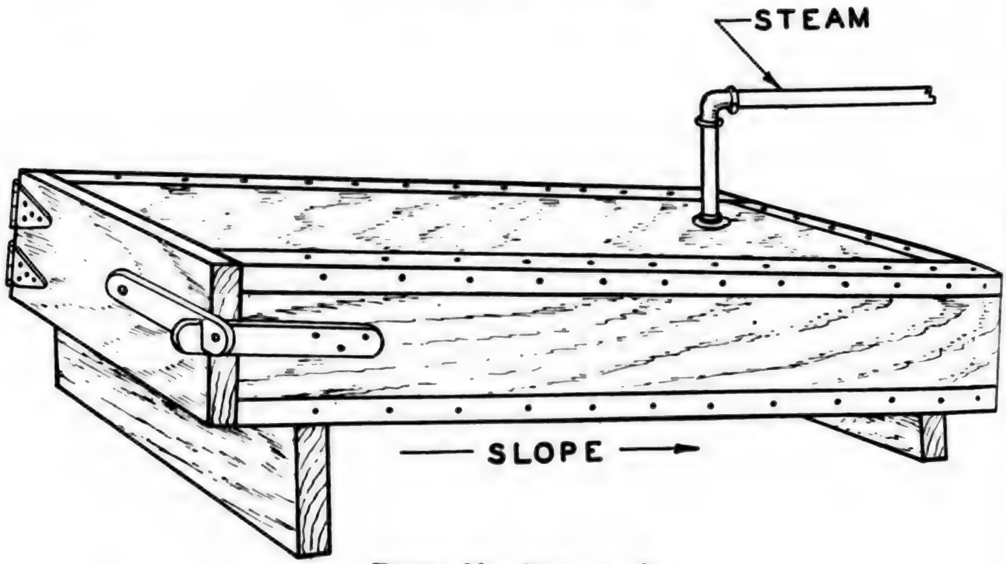


FIGURE 90.—Steam tank.

then bent over the forming die as in figure 92③. If the type clamp shown in figure 92③ does not hold, a vise type may be substituted; or the clamp and strap may be replaced by a vise type clamp with outer and inner forming dies. Bent pieces having greater depth (dimension in the direction of the radius of the bend) than width are best obtained by ripping a wide piece bent to the required shape.

(5) After bending, the wood should be permitted to remain in the forms until it is sufficiently dry to retain its shape. It is essential

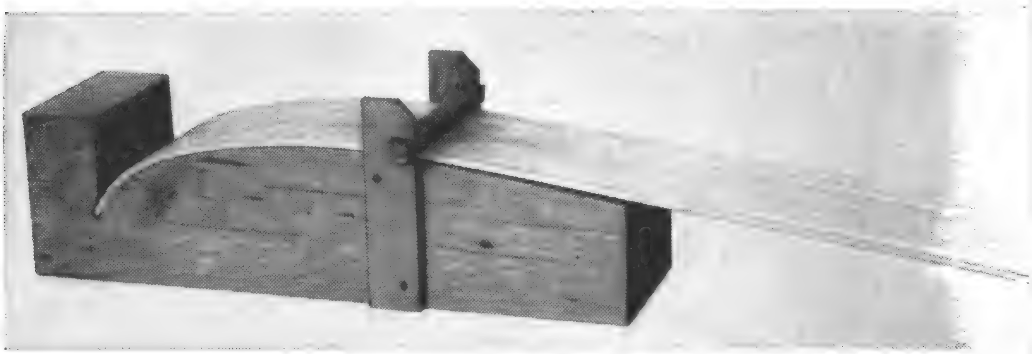


FIGURE 91.—Form for bending cap strips.

that the curvature of the forms used be slightly sharper (shorter in radius) than that required in the finished part, as the pieces tend to straighten out slightly when removed from the forms. It is also essential that the form be designed so that as much of the bent piece as possible is exposed to the air to facilitate drying.

c. Bending laminated members.—(1) Laminated wood members which do not require severe bending may be formed without steaming or other softening preparation. Wing tip bows are usually con-

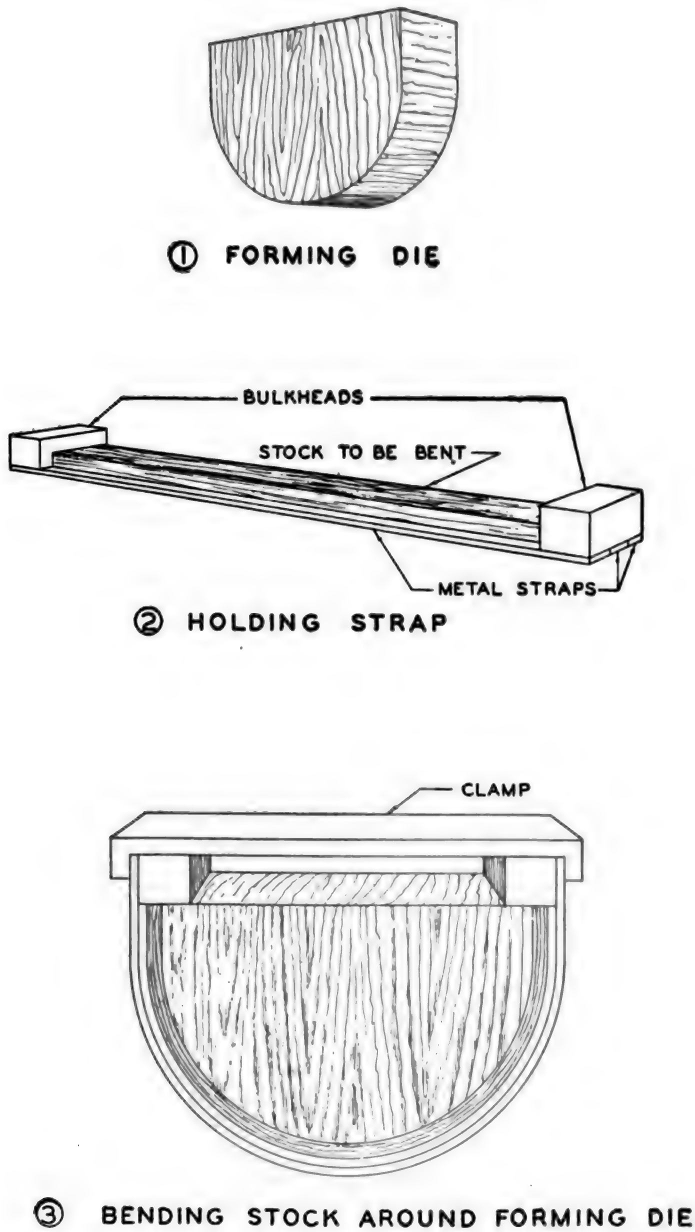


FIGURE 92.—Use of holding strap and forming die.

structed in this manner. Laminations sufficiently thin to take the required bend without splitting are first cut to size and planed on both sides. A sufficient number to make up the desired thickness of the member are then coated with glue and immediately clamped in a form of the required shape (fig. 93). A steel strap may also be used to hold the laminations over the forming die (see fig. 94). After the glue has set and sufficient time has been allowed for the wood to dry thoroughly, the member will retain the shape of the form with little, if any, spring-back. In cases where severe bending is necessary

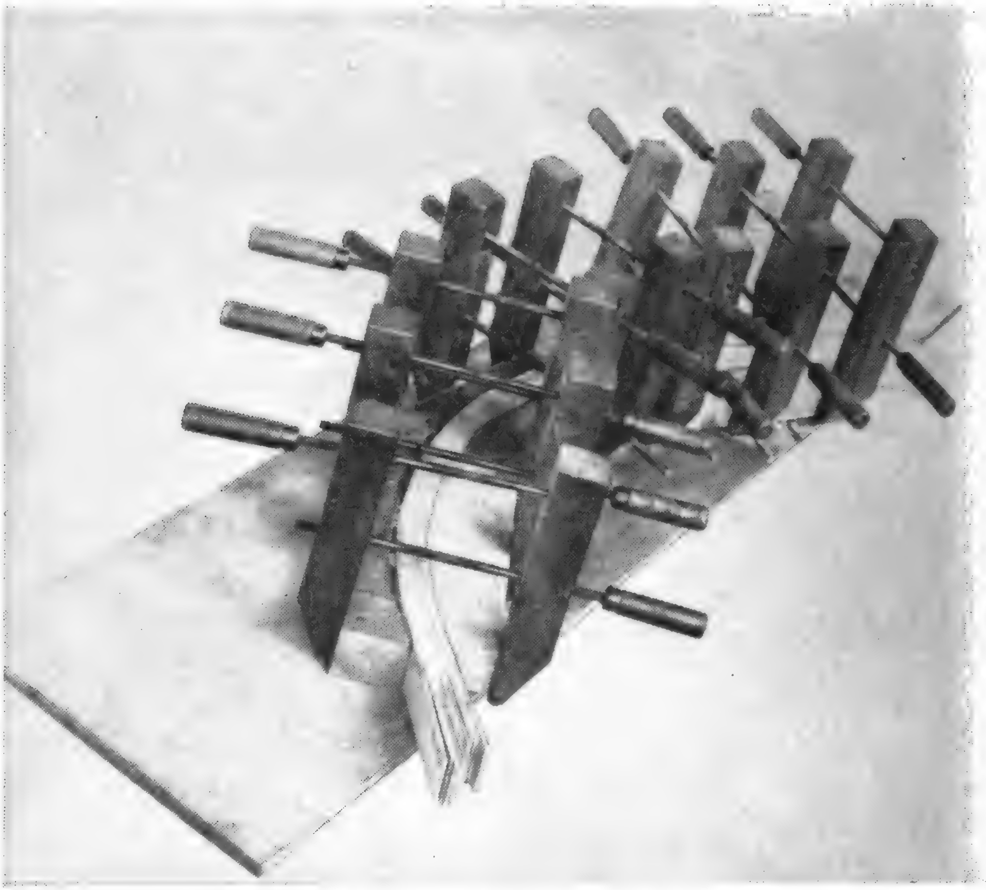


FIGURE 93.—Holding bent laminae with clamps.

or where it is not desired to have extremely thin laminations, steam softening may be necessary. In this case the laminations are steamed and bent to shape and then glued together.

(2) Where a bend is required in the end of a solid member, such as a spar flange or a stabilizer leading edge, the member is first slotted (see in fig. 95①) the length of the required bend. A spline is next inserted in the slot (fig. 95②), after applying glue to the surfaces. The member is then bent to the required curvature (fig. 95③).

d. Bending plywood members.—Curved plywood members may be made either by bending and gluing several layers of veneer in one operation, or simply by bending prepared plywood.

(1) Built-up plywood members are made by bending veneer sheets or strips over a form (fig. 96①), after applying glue to the surfaces. The sheets are held together until the glue sets, after which the member retains its shape when removed from the form (fig. 96②). The grain of each successive layer of veneer is at right angles to that of the adjoining layer. However, in some instances the veneer is

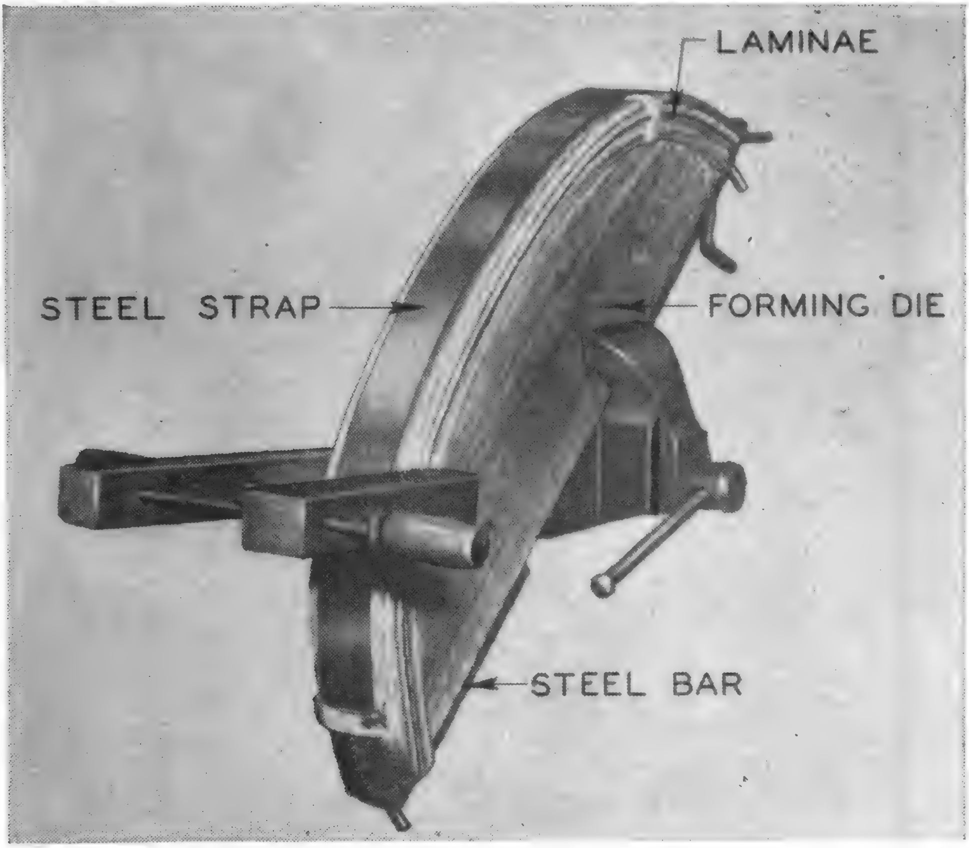


FIGURE 94.—Use of steel strap in bending laminae.

applied on the form with the grain running at an oblique angle (approximately 45°) with respect to the axis of the member. The advantages of built-up plywood members are similar to those for bent laminated members.

(2) Such parts as the covering for the leading edge of a wing or stabilizer may be formed of plywood which has been bonded with an adhesive subject to softening by heat. The plywood is first soaked in hot water or steamed until soft then bent over a form and clamped in place until dry (fig. 97). The curvature of the form should be slightly sharper than required so as to allow for a slight amount of spring-back.

55. Splicing wooden members.—*a.* The scarf joint (fig. 98) is most generally used in splicing wooden aircraft members. The two portions to be joined are beveled to identical slopes, which should be in the ratio of 10 to 1 for softwood and 15 to 1 for hardwood and plywood. Both parts should fit together accurately as the strength of the joint depends upon maximum contact between the two wood surfaces. Since it is usually difficult to obtain a true surface with hand

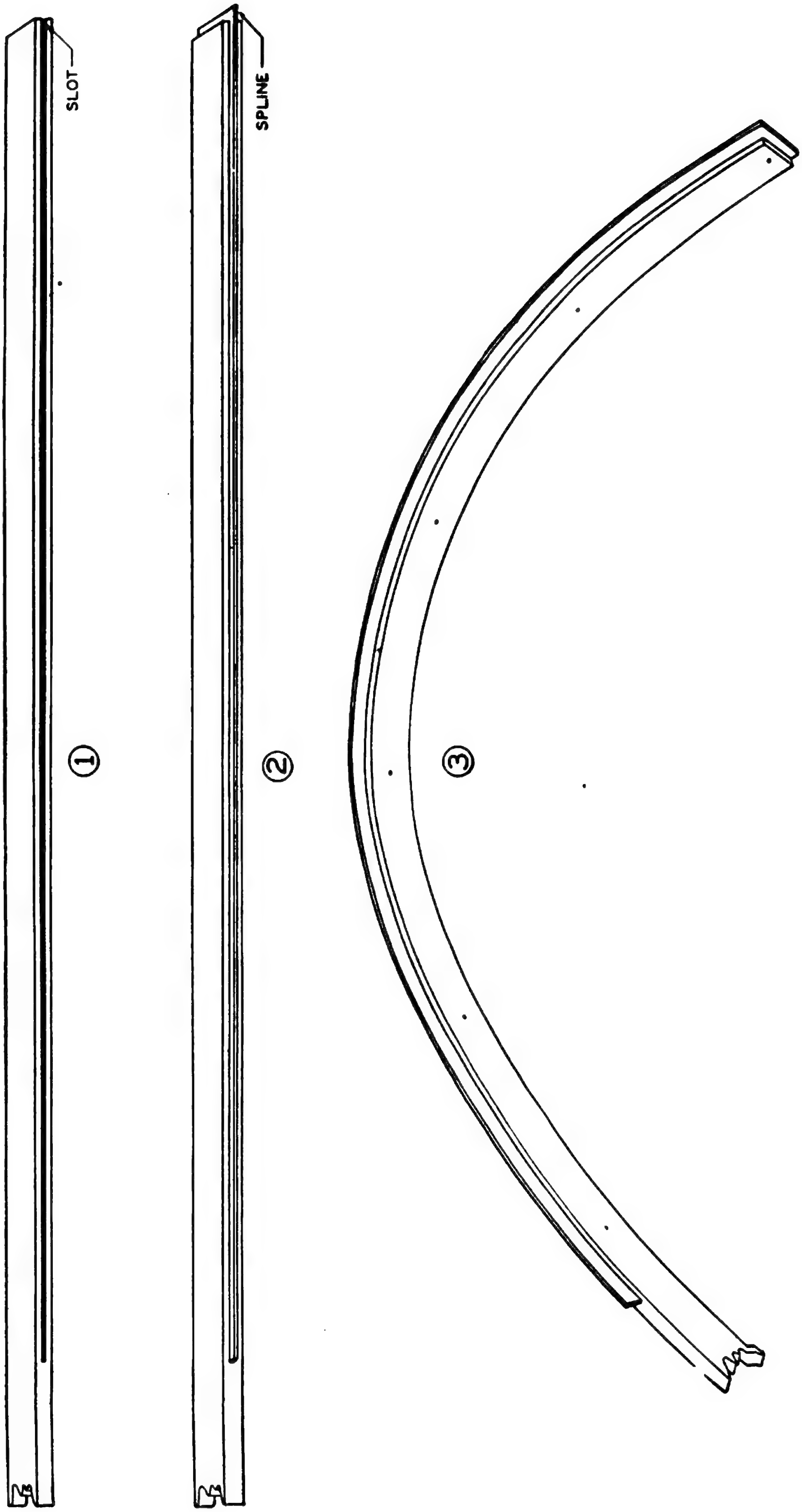


FIGURE 95.—Bending a solid member, spline method.

FIGURE 96.—Bending and gluing veneer sheet.

tools, a power jointer should be used in beveling the parts whenever it is possible to do so. Any irregularities in the surfaces may be detected by applying colored chalk to the beveled areas, fitting the pieces together, and then sliding one piece over the other with a slight motion. High spots will be indicated where the chalk is rubbed off.

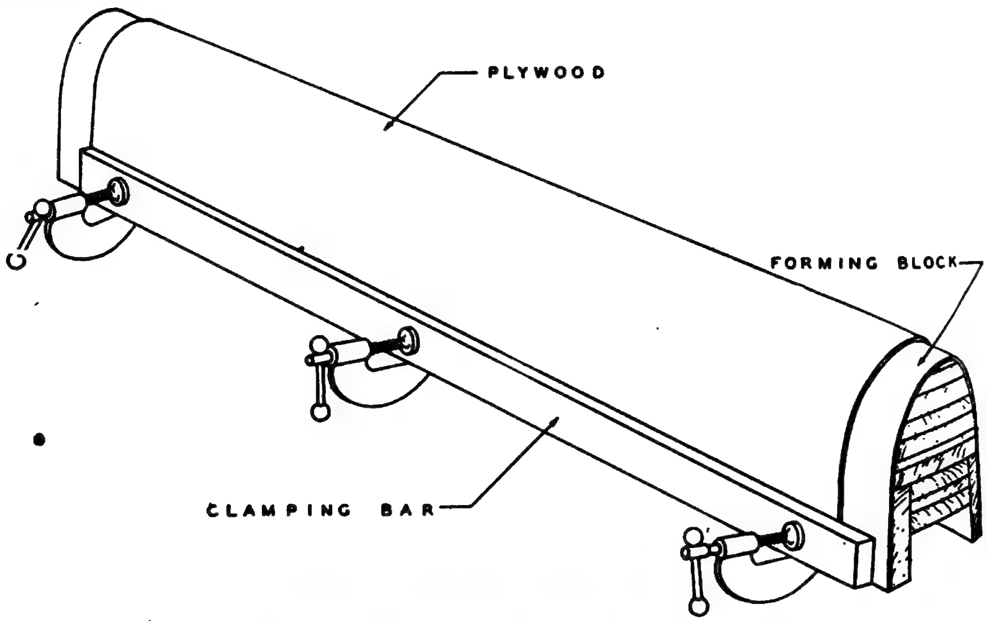


FIGURE 97.—Bending plywood over form.

NOTE.—Plywood must be soaked in hot water before attempting to bend over form.

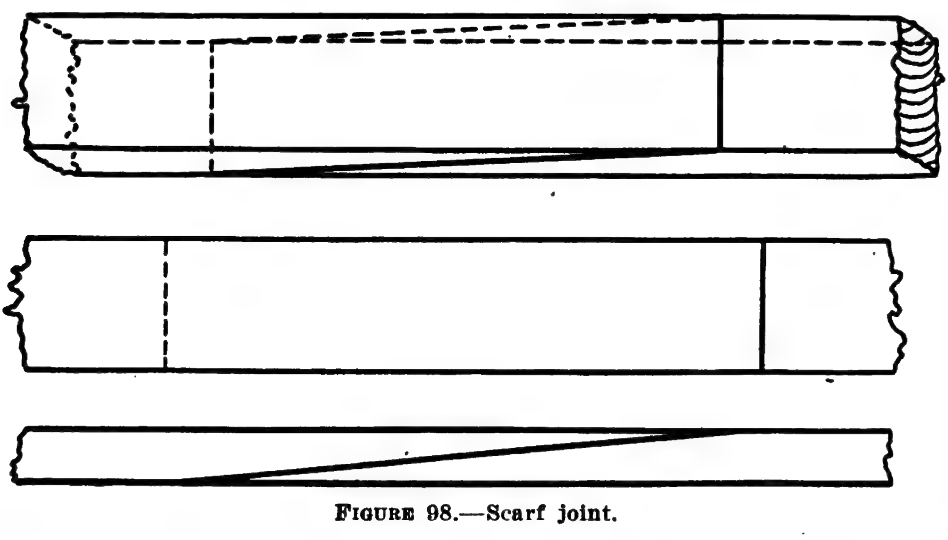


FIGURE 98.—Scarf joint.

These spots may be removed by planing or scraping. After a satisfactory fit is obtained, the chalk should be carefully removed with a scraper and the joint properly glued. Sandpaper should not be used to smooth the surfaces of the joint, as the wood dust fills the pores and prevents the glue from penetrating properly.

b. Plywood may be scarfed with hand tools, such as a spoke-shave, scraper, plane, file, or chisel, or with a powes jointer.

(1) When cutting a scarf with hand tools, the desired width of the scarf is marked by a pencil line drawn parallel to the edge of the plywood (fig. 99①). The plywood is then fastened to a bench by means of nailing strips or clamps, with the edge to be scarfed even with the edge of the bench top. At least one roughing cut on three-ply plywood, and several on thicker plywoods, should be made and the slope checked after each rough cut. For three-ply plywood the width of the slope, when the roughing cut is taken to the first ply, should be approximately two-thirds the width of the finished scarf as shown in figure 99②. The cutting is continued until the scarf is full width and a featheredge produced (fig. 99③). To prevent splintering the featheredge, a light cut should be made in the direction of the grain of the last ply.

(2) When cutting a scarf on a jointer a guide block is used in place of the jointer fence, to obtain the desired slope.

c. When it is necessary to splice a section onto a beam or spar which is in an assembly (fig. 100), a hand saw and plane are ordinarily used since it is not always feasible to remove the member. A scarf is first cut on both the member and replacement part as accurately as possible by hand. The parts are then assembled and held tightly together at the joint by means of a straight piece of plank clamped to the assembly as shown. If the parts do not fit together perfectly, a saw is run through the joint and the pieces again brought tightly together by tapping the outer end of the replacement part. This operation is repeated until maximum contact between the surfaces is obtained. Unless an extremely fine-toothed saw is used, it may be necessary to smooth the surfaces with a plane. The member is then lined up perfectly straight and the joint glued.

d. Cap strips are usually scarfed with a dovetail saw (see fig. 37). Glue is then applied to the surfaces and pressure applied to the joint by means of clamps (see fig. 40①).

e. When gluing surfaces involving end grain wood or surfaces cut at an angle to the direction of grain, such as scarf joints, the surfaces should be sized with a glue mixture somewhat thinner than that used for regular gluing. A sizing mixture of one part glue to three parts water (by weight) is used for casein glue. The sizing coat should be allowed to dry on the wood surfaces before applying the gluing mixture. The mixture for the final gluing should be thicker than for ordinary gluing (about one part glue to one and eight-tenths parts water). Both surfaces of the joint should be coated

405091°—43——8

with glue. To insure that pressure is evenly applied to the glued joint, pressure blocks should be used (see fig. 101).

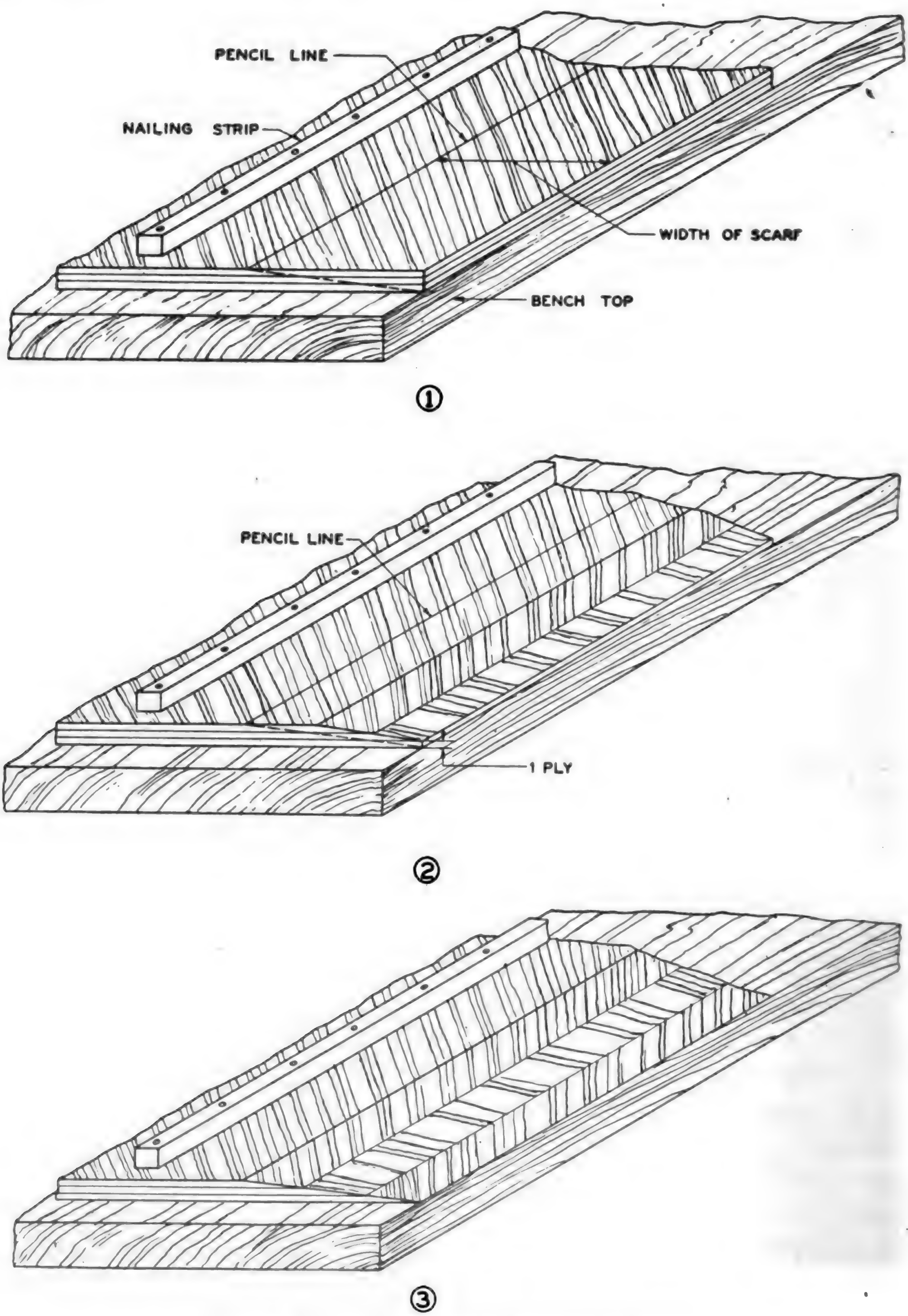


FIGURE 99.—Cutting scarf on plywood by hand.

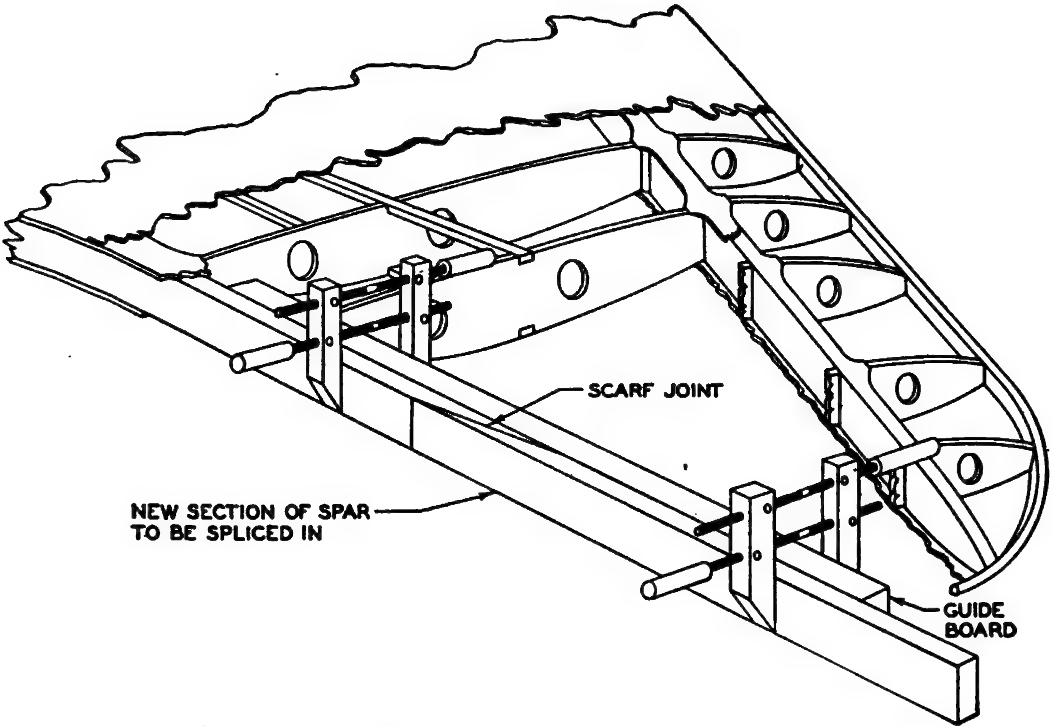
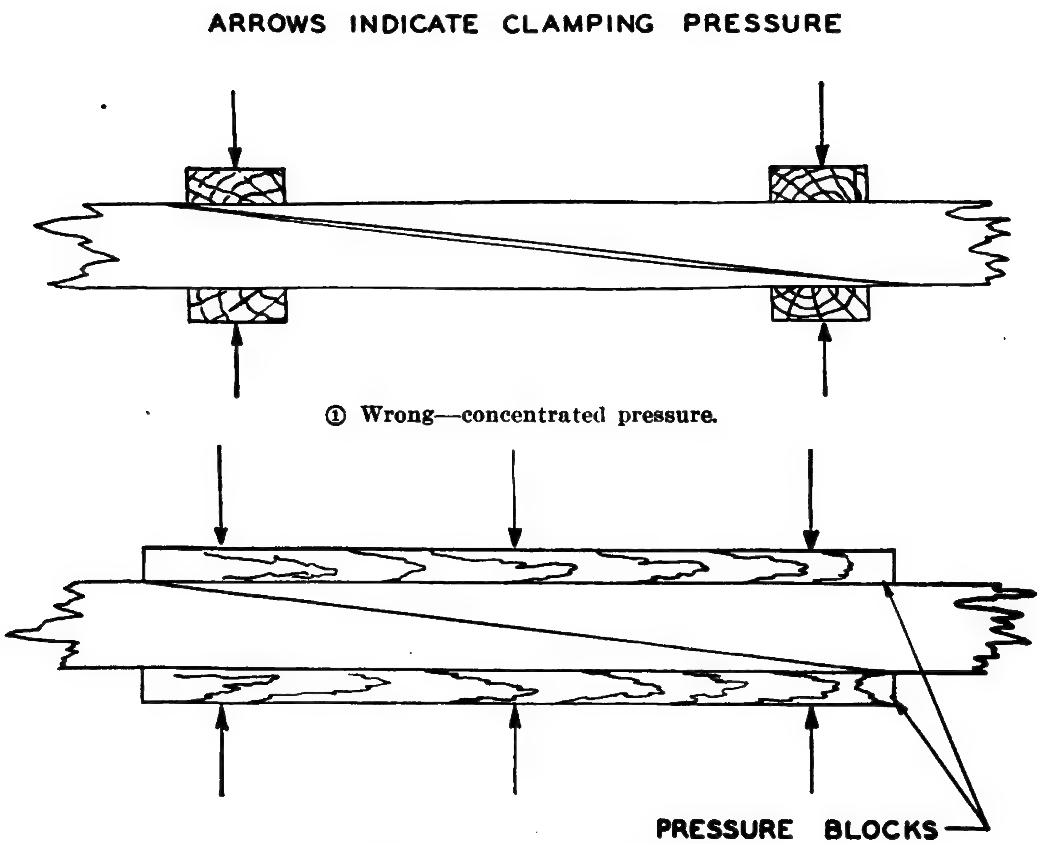


FIGURE 100.—Splicing section into beam or spar assembly.



① Wrong—concentrated pressure.

② Right—equalized pressure.

FIGURE 101.—Use of pressure blocks.

56. Wing spar construction and repair.—*a. Construction.*—Spars or beams transmit the air loads from the wing to the fuselage. These members extend from wing tip to wing tip or from wing tip to fuselage, depending on design. The wing fuselage fittings, ribs, and compression struts are attached to the spar. Cross sections of various types of spars are shown in figure 102. The rectangular and laminated solid spars occcasionally have reinforcing blocks glued on at the point of attachment of fittings and members. The use of I-spars, internally routed spars, and box spars result in a saving of weight. At points of attachment of fittings and members to an I-spar, reinforcing blocks are glued on, or the spar is left solid; at such points the internally routed spar is left solid. The box spar consists of an upper and lower flange connected by plywood webs. Bulkheads are used for bracing the plywood webs against buckling. Bulkheads also serve as reinforcing blocks at points where fittings and members are attached. Figure 103 shows part of a wing spar root fitting being assembled to the root end of a box spar, and the aluminum alloy bushings through which the fitting attachment bolts are inserted. These bushings provide more bearing surface on the wood and lessen the possibility of local crushing of the spar. Bushings are usually press fitted into the member. The penciled outline on the web locates the position of the reinforcing blocks to which the plywood web is nailed and glued. To permit ventilation and drainage of moisture condensed within the spar, small holes are drilled through the rear web at the lowest point of each compartment. Water will drain from the compartments when the airplane is in a taxying position. The inside of the spar and all holes are waterproofed with varnish.

b. Repairs.—(1) *Splicing of spars.*—A spar may be spliced at any point except under wing fittings, or engine mount fittings when engine nacelles are located on the wings. Not more than two splices (excluding any splices the manufacturer may have incorporated in the original fabrication of the airplane) is considered satisfactory. Acceptable methods of splicing various types of spars are shown in figures 104 to 107, inclusive. An acceptable method of splicing box spar webs is shown in figure 108. Two methods of splicing box spar flanges are shown in figures 109 and 110.

(2) *Elongated bolt holes.*—(*a*) In case of elongated bolt holes in a spar or cracks in the vicinity of bolt holes, unless the method of repairing such holes is specificially approved, a new section of spar should be spliced in or the spar replaced entirely. In many cases it has been found advantageous to laminate the new section of the spar

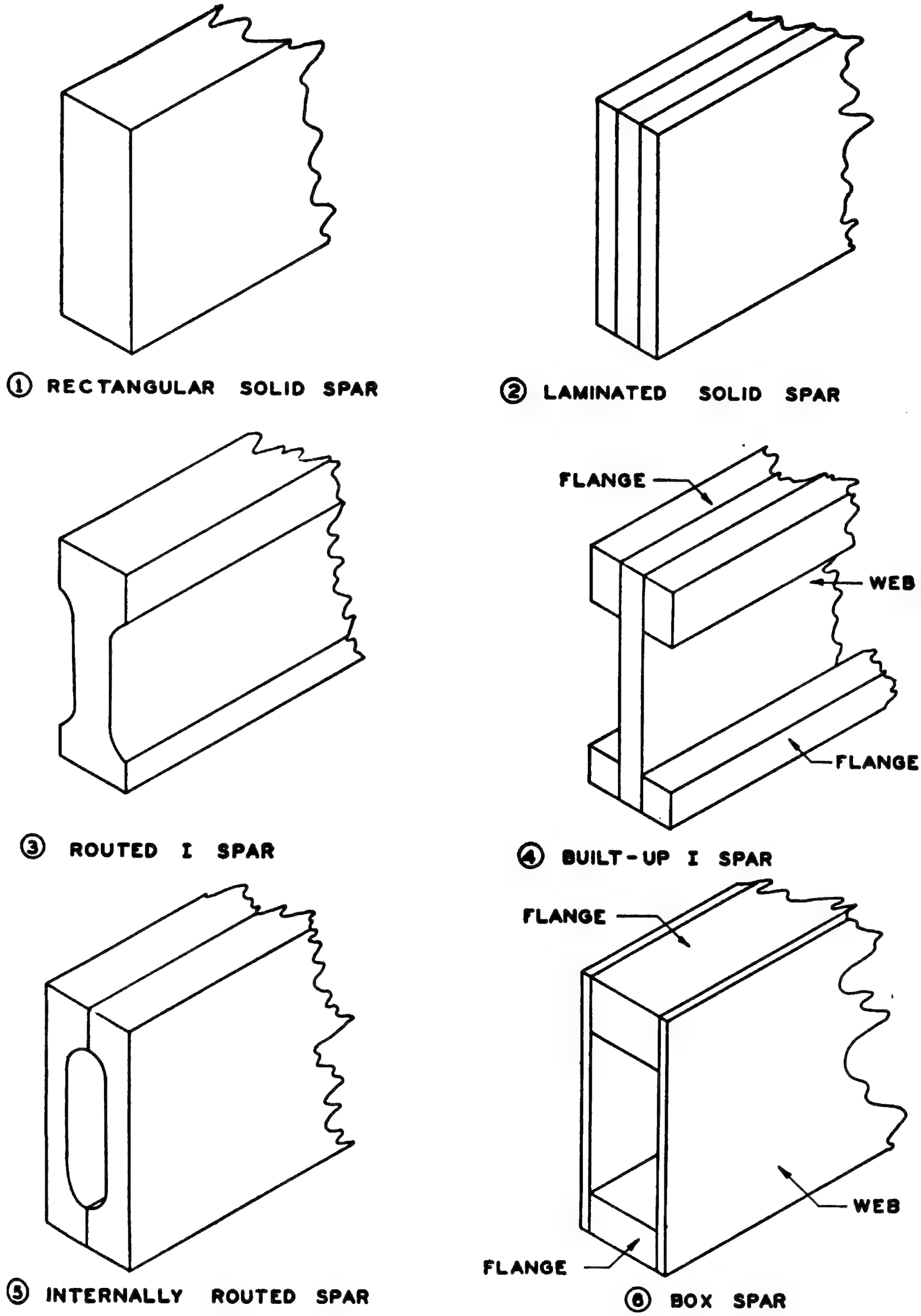


FIGURE 102.—Spar cross sections.

(using aircraft plywood for the outer faces), particularly if the spar roots are being replaced. Reworking of the bolt holes is accomplished in conjunction with reworking the spar. Care must be exercised to hold newly reamed holes concentric about the center lines of the original holes.

(*b*) Where the root end of a spar is to be reworked, the flush filler block repair is recommended. Damaged holes should be cleaned out to remove crushed material and wooden plugs installed. The spar is then scarfed and flush filler blocks, which should be of suitable hardwood, glued in place (see fig. 111). After the glue has set, the spar is redrilled for the insertion of bushings of the same size as the original. The ends of the bushings should set approximately $\frac{1}{64}$ inch below the surfaces of the spar in order to allow the fittings to grip the spar properly. Plugs should be installed with the grain running parallel to the grain of the spar.

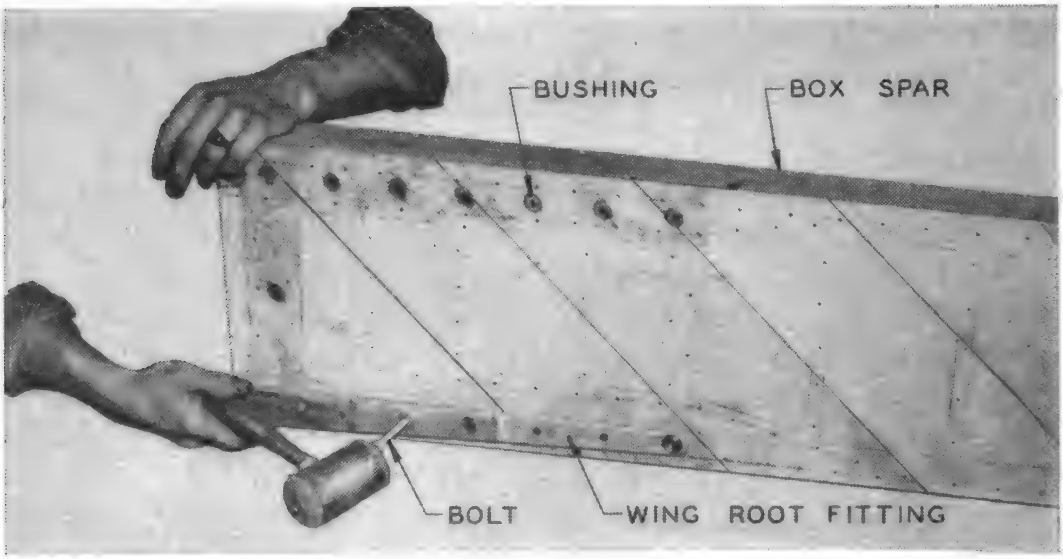


FIGURE 103.—Use of aluminum alloy bushings.

(*c*) Damaged holes at wire point ends or rod end fittings may be repaired by removing the original filler blocks, plugging the affected holes, installing new filler blocks, and redrilling as described in (*b*) above.

(3) *Removing bacteria or fungus growth.*—Bacteria or fungus growth at filler block glue joints should be removed by scraping away the growth, and with a suitable instrument, working into the glue joint to remove all traces of the growth. The area of the glue joint which has been scraped should be filled with new glue and the spar refinished. Careful inspection should be made to determine whether

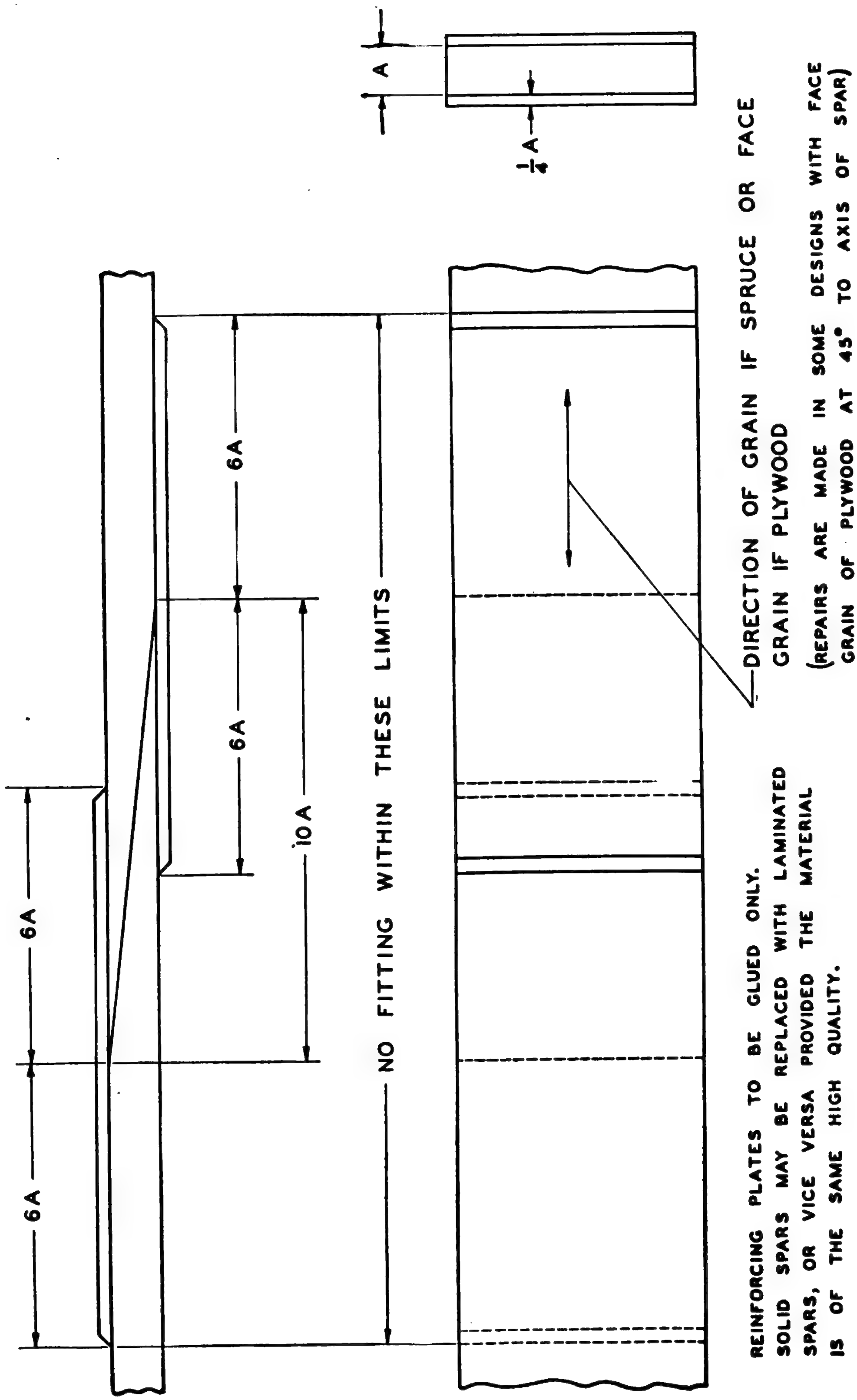


FIGURE 104.—Method of splicing solid or laminated rectangular spar.

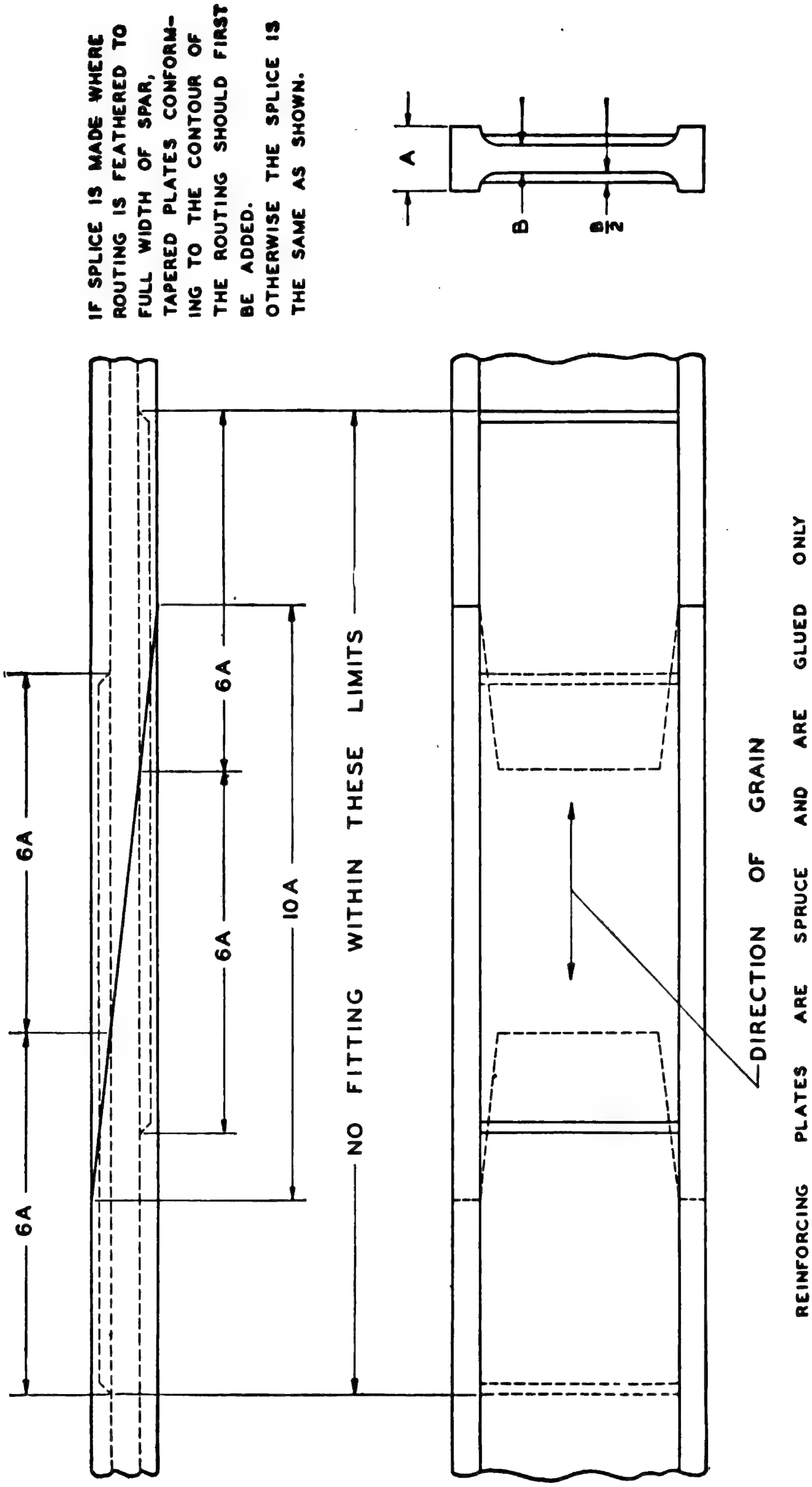


FIGURE 105.—Method of splicing solid I-spars.

or not a fungus growth has penetrated into the depth of the glue joint to any great extent. If inspection reveals a penetrated fungus growth, the filler block should be removed, all growth and glue scraped from the spar, and a new filler block glued in place.

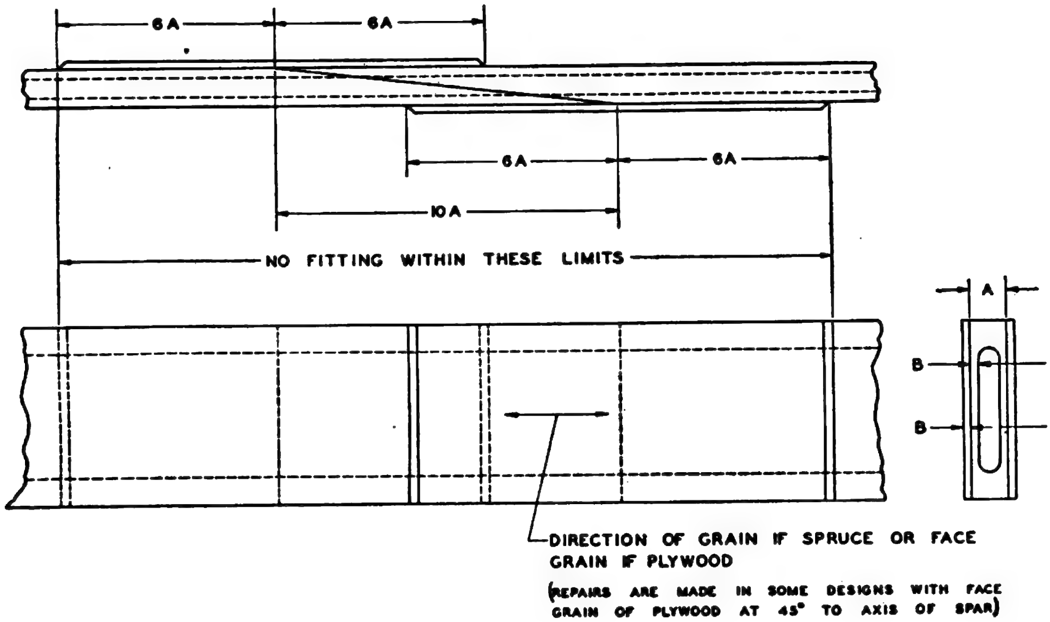


FIGURE 106.—Method of splicing internally routed spar.

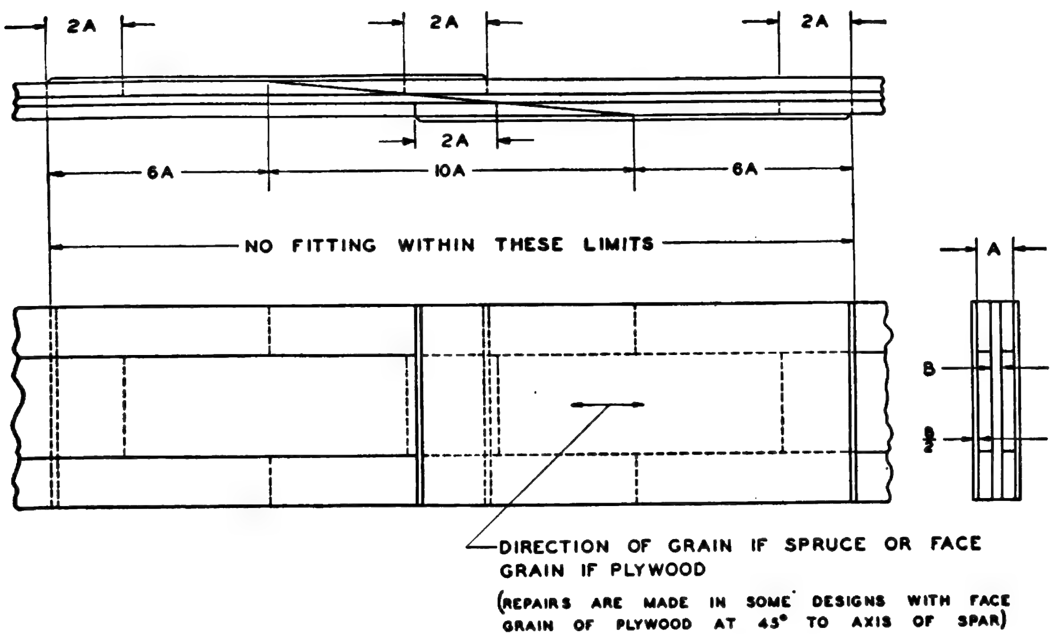


FIGURE 107.—Method of splicing built-up I-spar.

(4) *Longitudinal cracks and local damage.*—Cracked spars (except box spars) may be repaired by gluing plates of spruce or plywood to

both sides of the spar. Such plates should extend well beyond the termination of the cracks and be of sufficient thickness to develop the longitudinal shear strength of the spar. A total thickness of the spar web or total thickness of the plywood equal to one-fourth the spar web thickness should be used (see fig. 112). A method of repairing small local damage to either the top or bottom side of a spar is also shown in this figure.

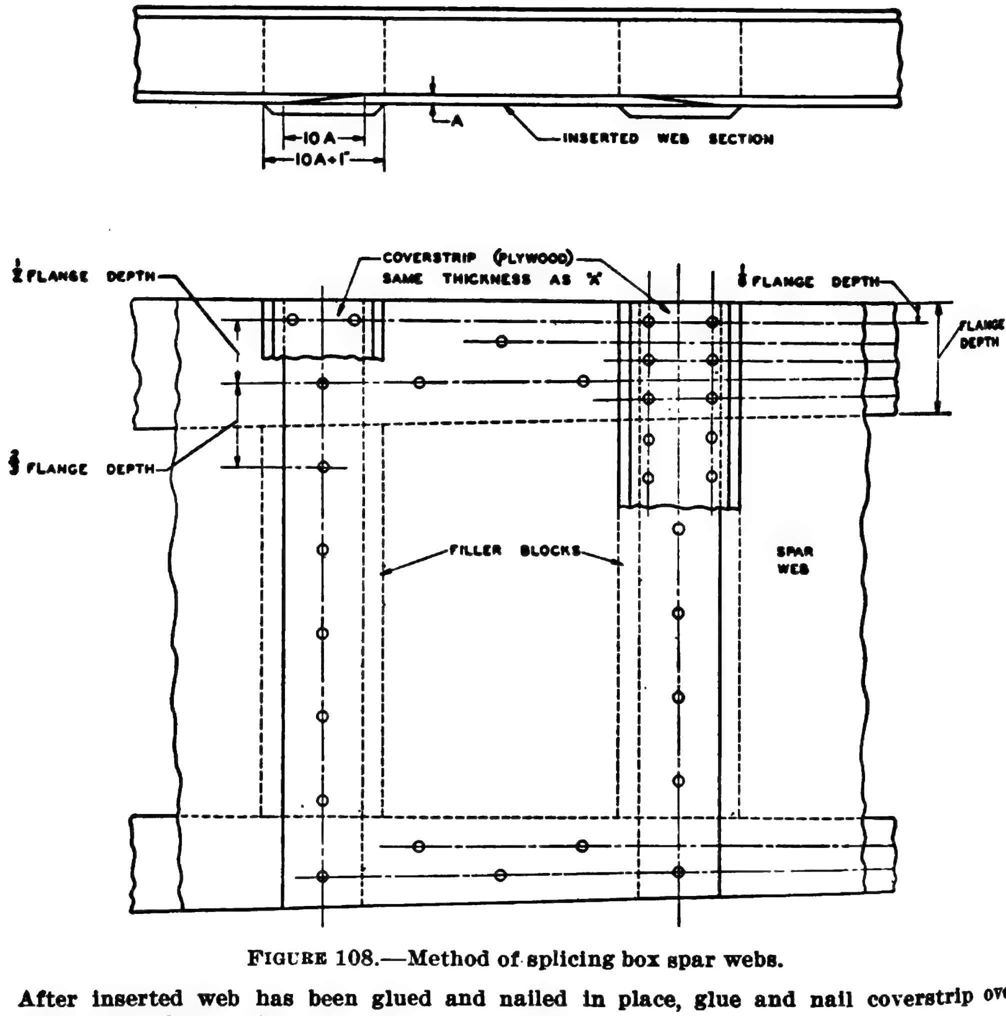


FIGURE 108.—Method of splicing box spar webs.

After inserted web has been glued and nailed in place, glue and nail coverstrip over entire length of splice joints.

Sectional shape of filler blocks must conform exactly to taper of spar. They must not be too tightly fitted or wedging action will loosen existing glue joints of webs to flanges. If too loosely fitted, crushing of web will occur when clamping.

(5) *Replacing solid type spars with laminated type.*—Solid spruce spars may be replaced with laminated ones or vice versa, provided the material is of the same high quality. External plywood reinforcements should always be replaced with plywood as in the original structure.

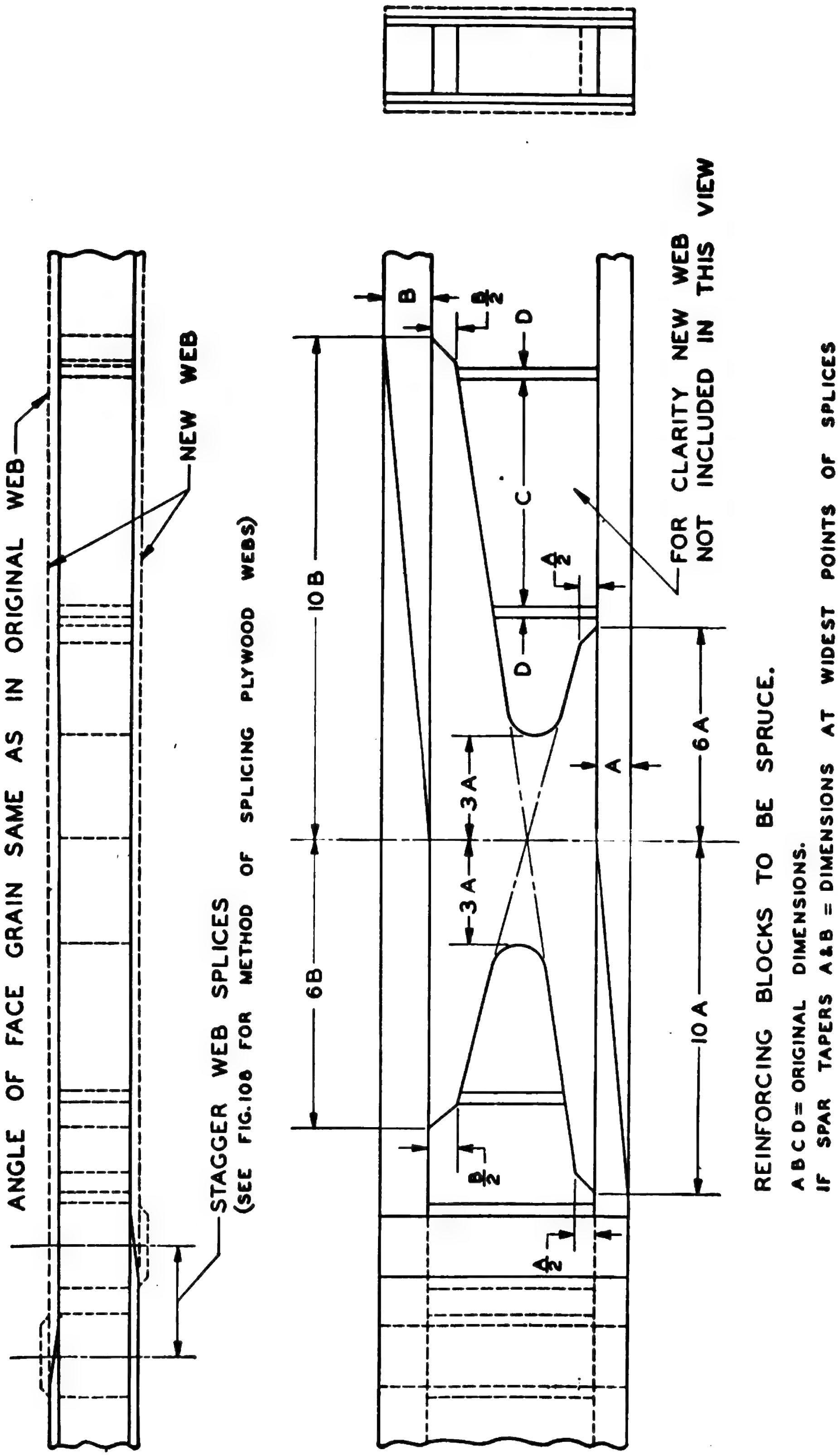


FIGURE 100.—Splicing box spar flanges using solid block.

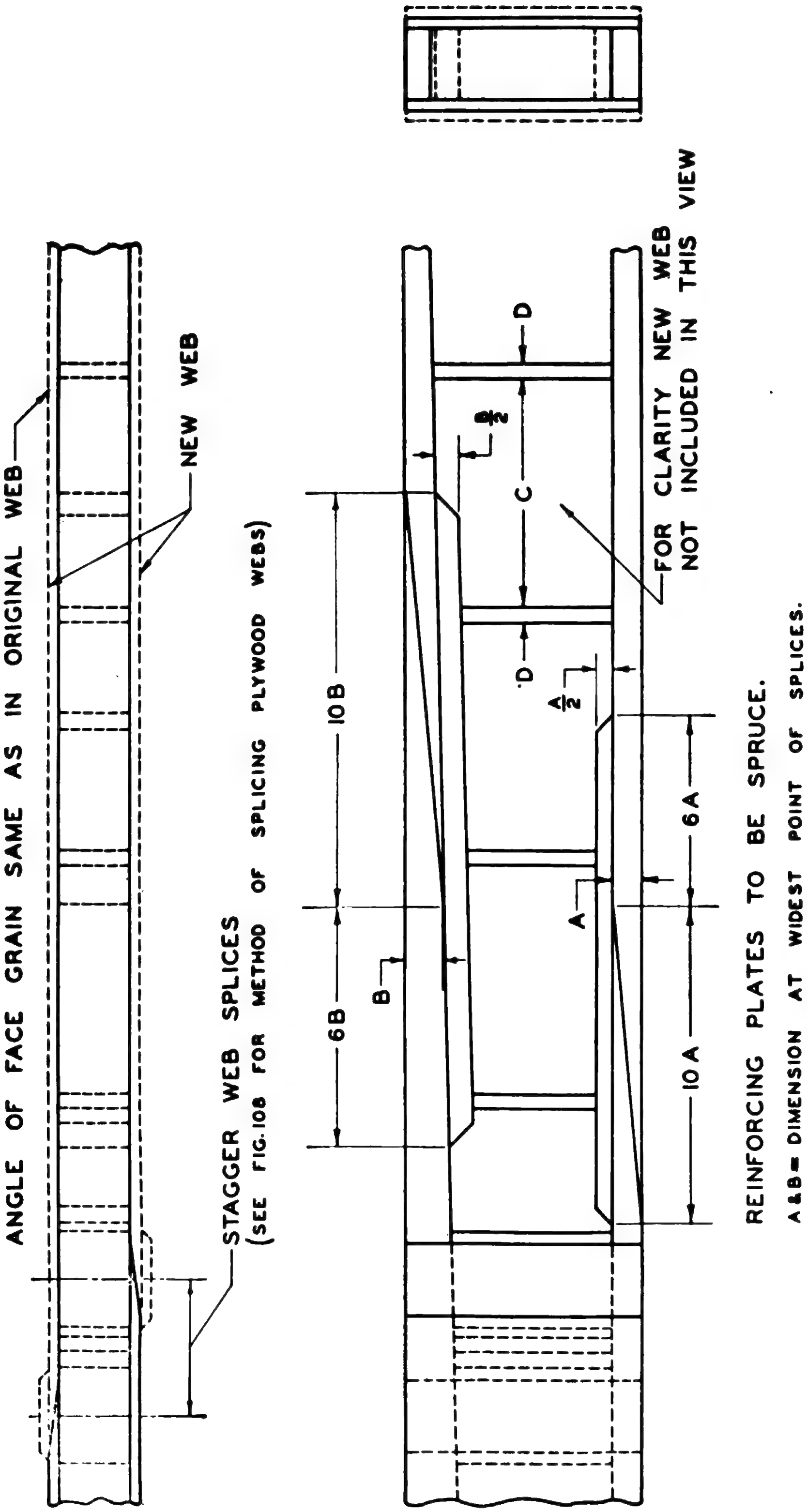


FIGURE 110.—Splicing box spar flanges—plate method.

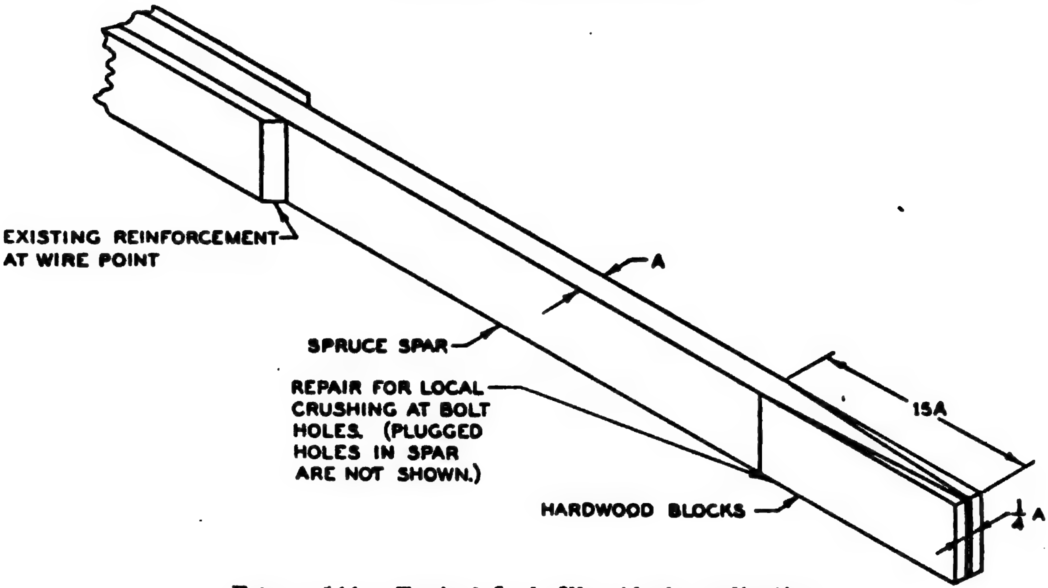


FIGURE 111.—Typical flush filler block application.

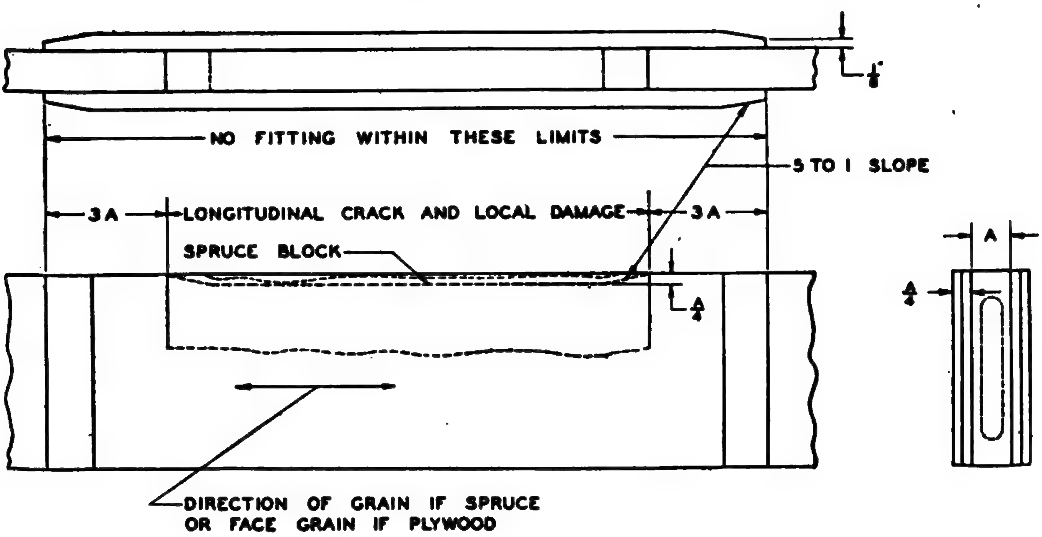


FIGURE 112.—Repairing local damage to spar.

57. Rib construction and repair.—*a. Construction.*—(1) *General.*—Ribs are used to give the wing and other airfoil sections the proper cross sectional shape. A tapered wing may be tapered in width or thickness or in both dimensions. The ribs of tapered wings vary in size from wing tip to wing root although the cross sectional shape (airfoil section) of each rib is the same throughout. A nontapering wing with spars of constant depth has the same size rib throughout, except possibly at the wing tip. In some wings, certain ribs are designed to take the compression load between the front and rear spars. In this case they replace the compression struts which would otherwise be separate members. Some ribs are constructed with the nose section, the center section between the spars, and the

trailing edge section as separate units, all of which are butted against the spar and fastened with glue and nails. Other ribs are constructed in one unit and are slipped over the spar to the proper stations. The rib structure may consist of the truss type with plywood gusseted joints, the lightened and reinforced plywood type, the full plywood web type with stiffeners, or other special design. Specific information on the construction of a rib is given in the engineering drawings for the particular airplane. Special care should be exercised in the construction and repair of ribs in order to maintain the proper wing cross section. Any change in the shape of an airfoil section changes its aerodynamic characteristics.

(2) *Rib lay-out.*—Complete ribs should preferably be made from a manufacturer's approved drawing or from an Army Air Forces drawing, except that the original rib may be used as a pattern in laying out the new rib if it is not too seriously damaged to permit comparison.

(3) *Rib jig.*—(*a*) The board on which the rib is assembled, called a rib jig, should have one side surfaced perfectly straight and level to insure that ribs which are made up are all alike and true. The rib lay-out can be transferred to the board by laying the drawing on the board and outlining it with a pin mark on either side of the ends of each member and at intervals along either side of the cap strip. The drawing is then removed and lines drawn through the proper pinholes.

(*b*) The guide blocks, used to hold the members in the correct position, are next properly located, fitted, glued, and nailed or screwed to the board (see fig. 113). The members should fit snugly between the blocks. The thickness of the blocks must be less than that of the rib members to allow clearance for gluing and nailing the gusset plates to the rib members.

(4) *Cap strip.*—Cap strips usually require bending in a form. Either solid or laminated strips are used. Wood ribs preferably should not be attached to wood spars by nails driven through the rib cap strips as this weakens the rib materially. The attachment should be by means of glue with cement-coated or galvanized nails driven through the vertical rib members on each side of the spar, or as otherwise specified in the drawing.

b. Repair.—Acceptable methods of repairing damaged ribs at a joint, between joints, at a trailing edge, or at a spar are shown in figures 114 and 115. When repairing control surfaces, especially on high performance airplanes, care should be exercised that the repairs do not involve the addition of weight aft of the hinge line. Such

procedure may adversely disturb the dynamic and static balance of the surface to a degree which would induce flutter. As a general rule, it will be required to repair control surfaces in such a manner that the structure is identical to the original so that the weight distribution is not affected in any way.

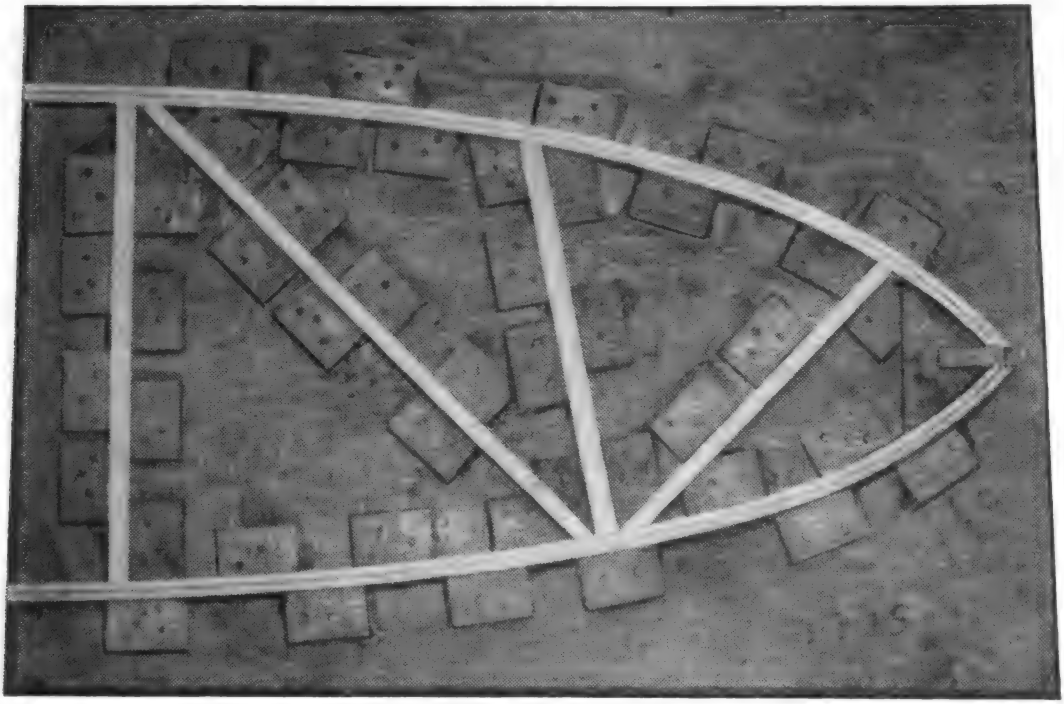


FIGURE 113.—Rib jig.

c. Repair of compression ribs.—Acceptable methods of repairing damaged compression ribs are shown in figure 116.

(1) Figure 116① shows the repair of a compression rib of the I-section type, that is, wide, shallow cap strips and a center plywood web with a rectangular compression member on each side of the web. The rib is assumed to be cracked through cap strips, web member, and compression member. Cut the compression member and remove and replace the shortest section, adding reinforcing blocks (see fig. 116③). Cut and replace the aft portion of the cap strips, reinforcing as shown in figure 114②, except that the reinforcing blocks are split in the vertical direction to straddle the center web. Plywood side plates are then glued on (see fig. 116①) to reinforce the damaged web.

(2) Figure 116② shows a compression rib of the type that is basically a standard rib with rectangular compression members added to one side and a plywood web to the other side. The method used in this repair is essentially the same as in figure 116① except that the

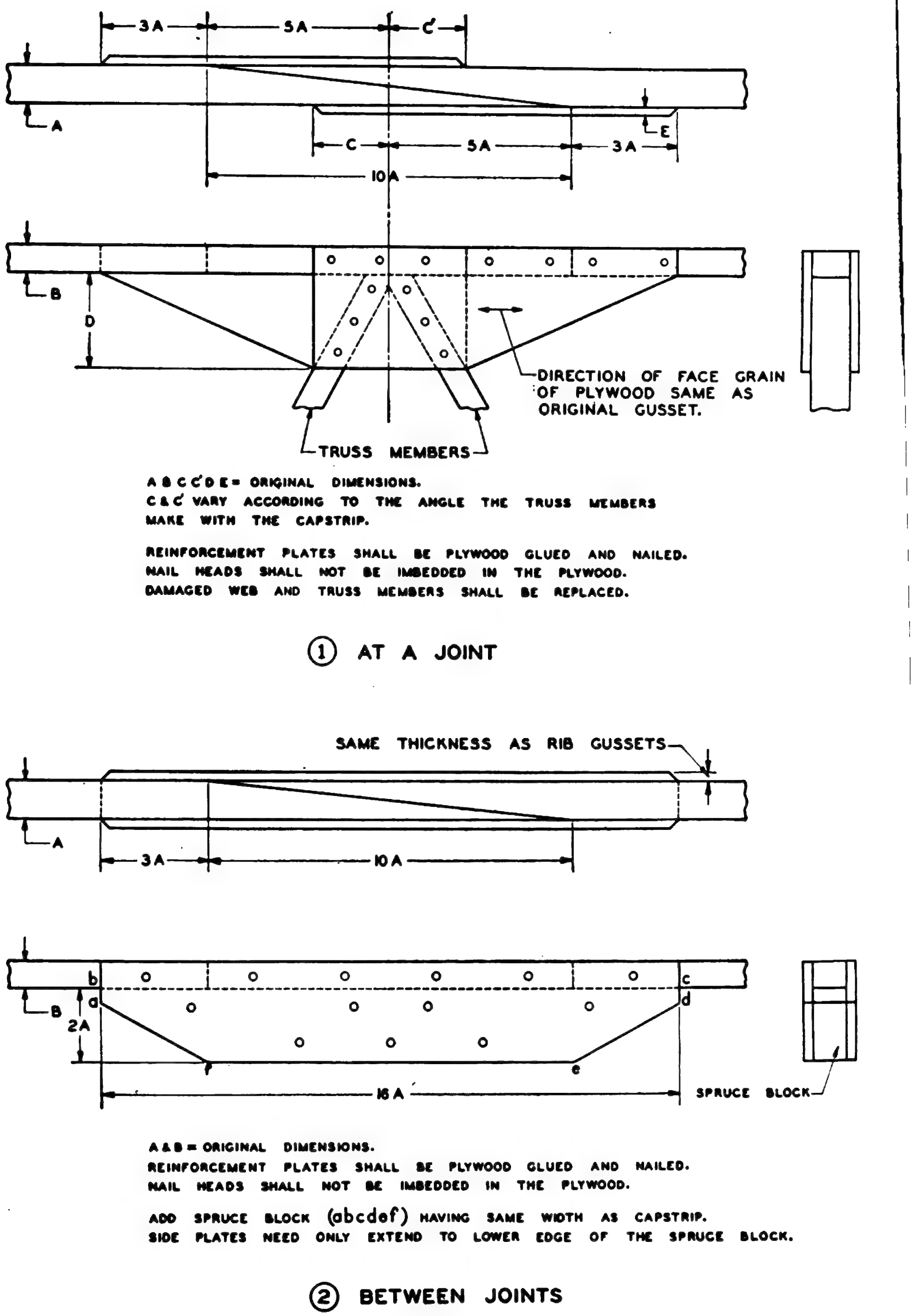


FIGURE 114.—Typical cap strip splices at a joint and between joints.

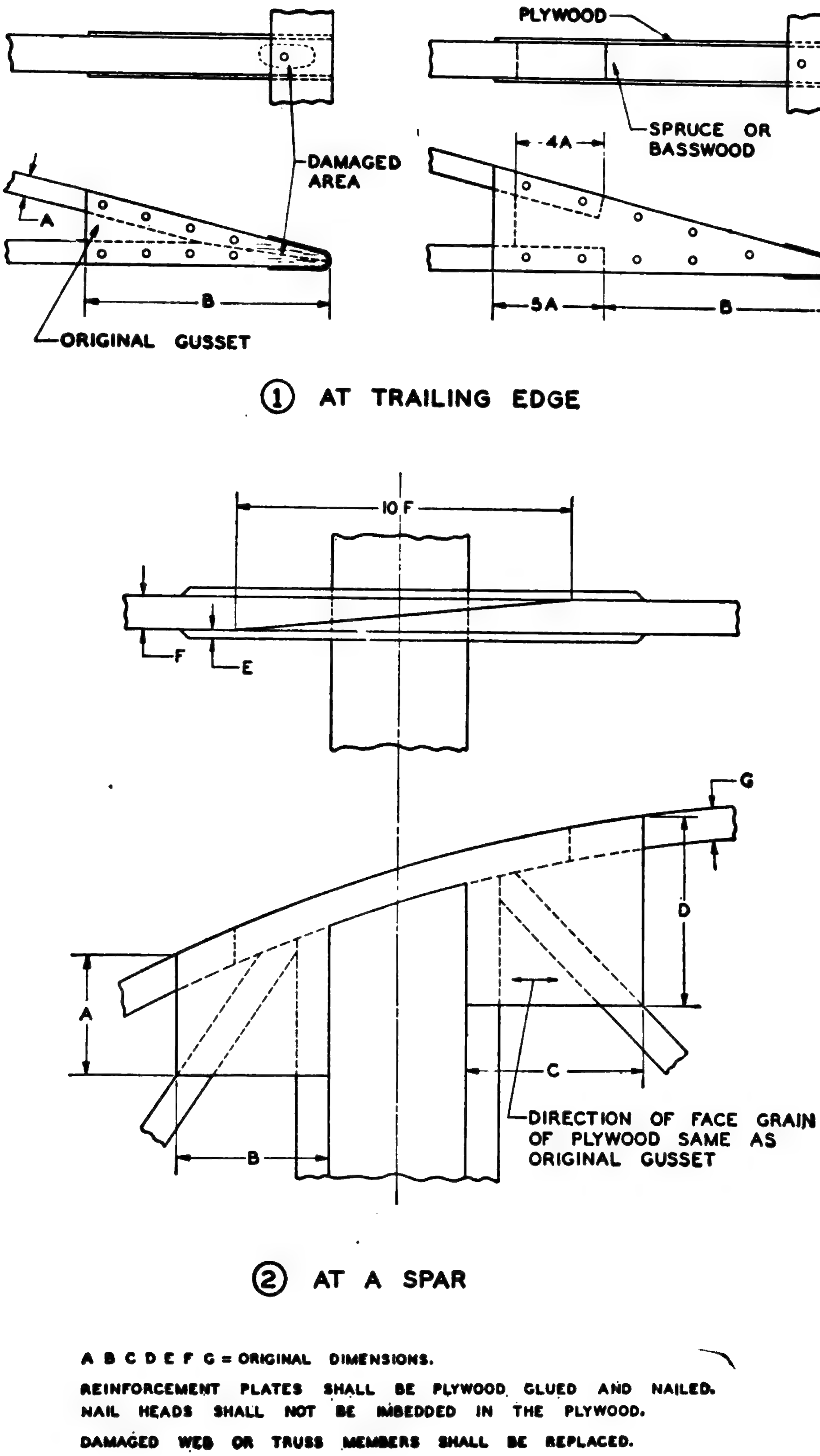


FIGURE 115.—Typical rib splice at trailing edge and at spar.

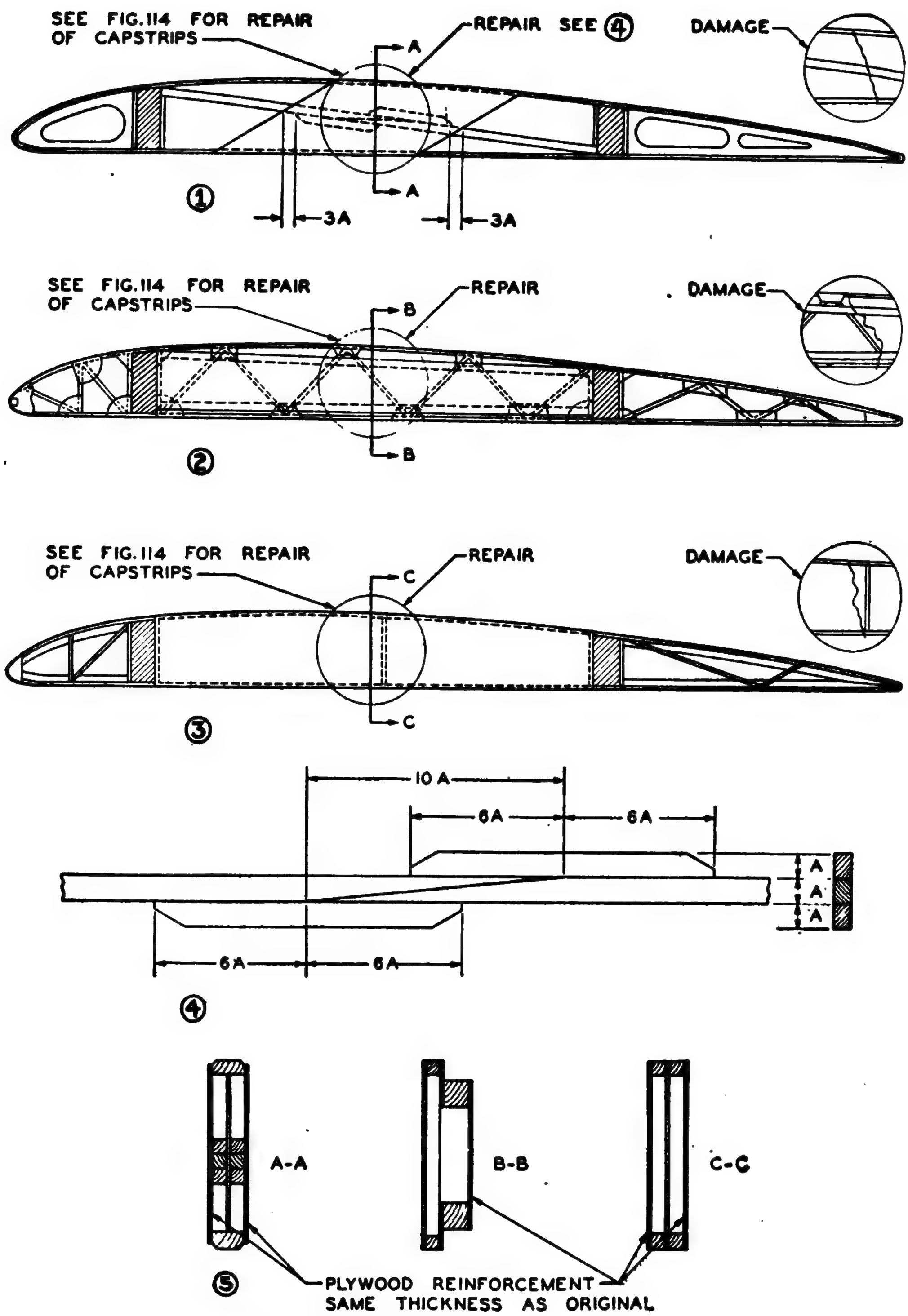


FIGURE 116.—Typical compression rib repairs.

plywood reinforcing plate (shown solid black in section B-B) is continued the full distance between spars.

(3) Figure 116③ shows a compression rib of the I-type with a rectangular vertical member each side of the web. The method of repair is essentially the same as that shown in figure 116①, except that the plywood reinforcing plates on each side (shown in solid black in section C-C) are continued the full distance between spars.

58. Leading and trailing edge strip.—*a. Construction.*—(1) Special nose ribs, stiffeners, and a covering of sheet metal or plywood are used to maintain the contours of the leading edge of the wing, aileron, or other airfoil surface, and to take care of local stresses. A metal or wooden strip is used along the leading edge to secure the ribs against sidewise bending and to provide a surface for attaching the fabric, metal, or plywood covering. In some designs the metal or plywood covering acts as the stiffener for the ribs in place of the leading edge strip.

(2) The curved portion of the leading edge strip completes the contour along the nose of the wing. In forming the leading edge of the strip, a template, corresponding to the curvature, is used to check the work (see fig. 117①). Templates for a tapered leading edge strip vary in shape to correspond to sections along the strip (see fig. 117②). Dimensions for laying out the template are taken from a drawing of the leading edge.

(3) The trailing edge strip of an airfoil surface may consist of wood or metal. The wooden strip is made in a manner similar to the leading edge strip, using templates where necessary to carry out the camber of the rib. Where a metal channel is used, the channel is riveted to the cap strip.

b. Repair.—Repairs to leading edges of wing and control surfaces should be made by properly executed and reinforced splices. A damaged leading edge section of a horizontal or vertical stabilizer may be repaired by splicing in a new section using the method shown in figure 118. The skin is feathered into the strip to give additional gluing area. If this is properly done, only the one reinforcing strip is necessary.

59. Wing tip bow.—*a. Construction.*—A wing tip may be elliptical, square, or circular in plan form. An elliptical or circular wing tip requires the construction of a wooden or metal wing tip bow to which the plywood or fabric covering is attached. A wooden bow usually consists of four to ten laminae, bent to the desired shape. If the upper surface of the wing extends level to the wing tip, the wing

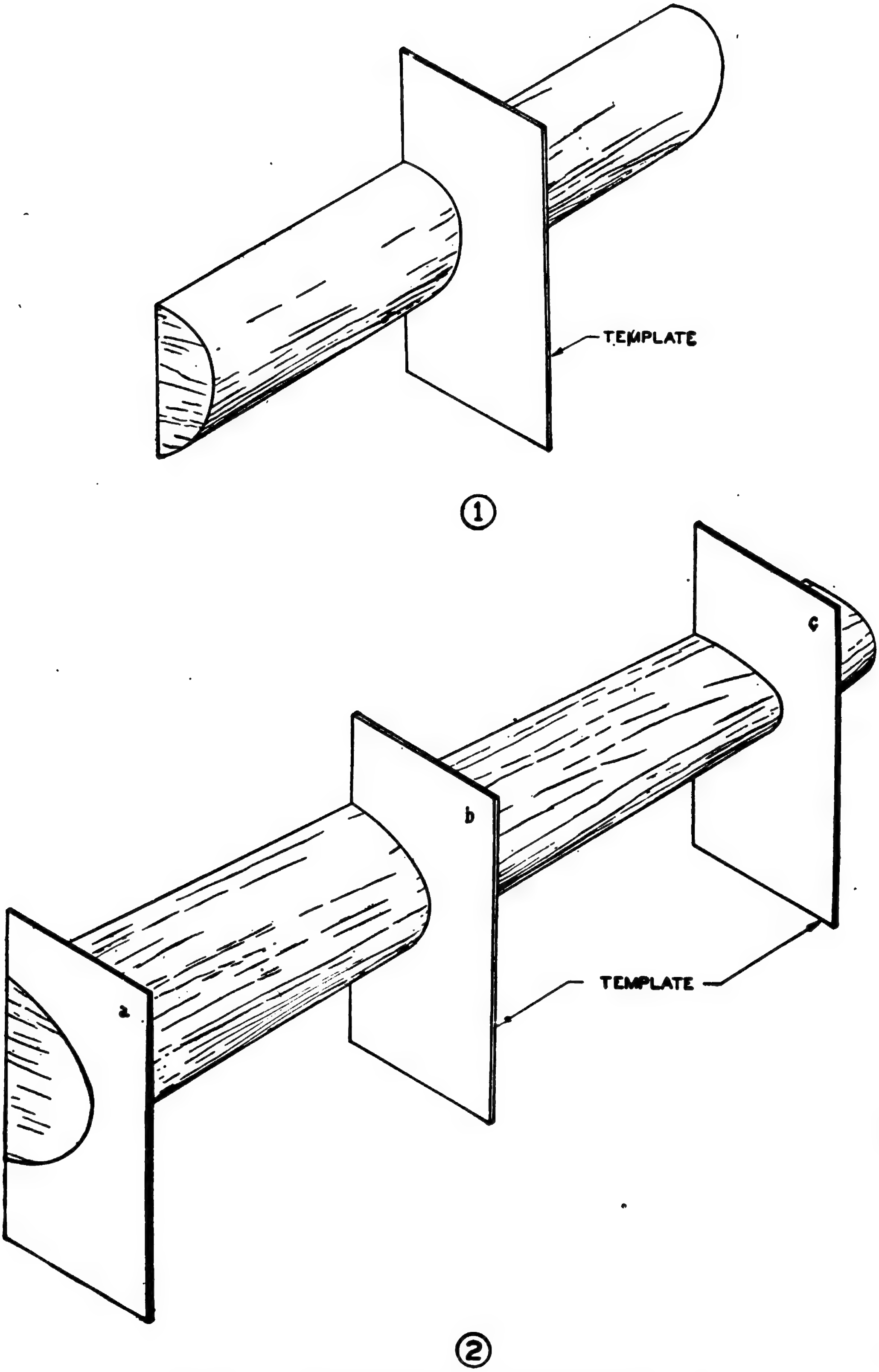


Figure 117.—Use of templates in shaping leading edge.

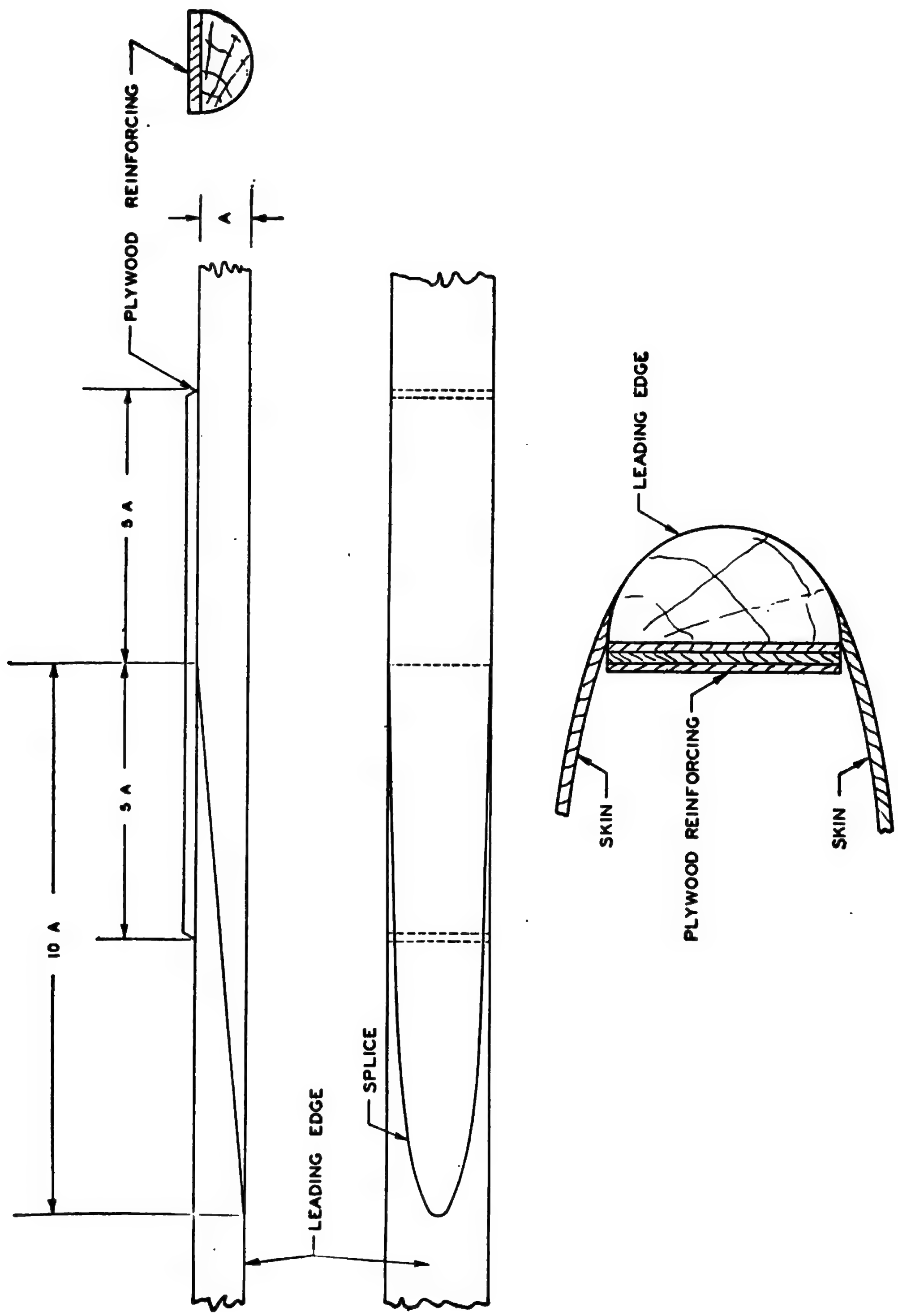


FIGURE 118.—Leading edge repair.

tip bow is curved upward from the leading edge (see fig. 119). Bow stock for this type bow is made wide enough so that the contour can be laid out on the curved stock and the bow sawed to shape on a band saw. After the bow is attached to the wing, it is worked to the desired cross section by hand, using a plane or spokeshave. Where

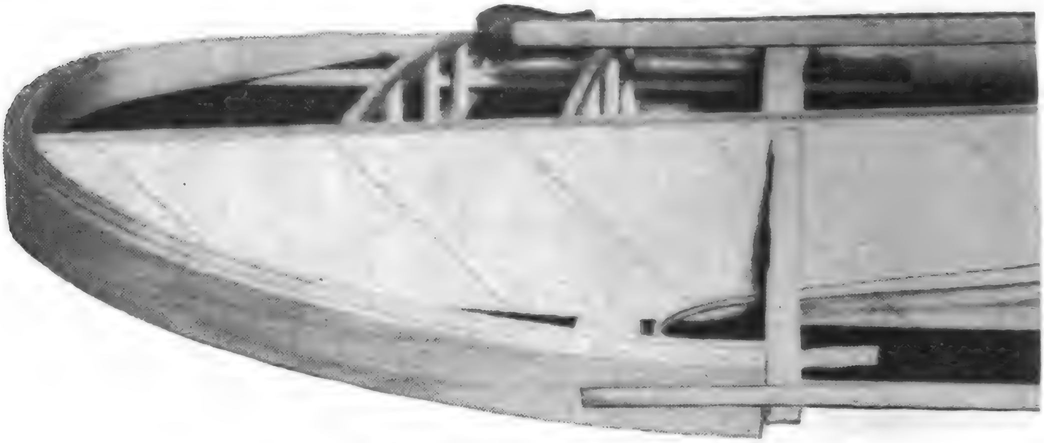


FIGURE 119.—Unfinished wing tip bow.

both the upper and lower surfaces of the wing slope to form the tip (fig. 120) the bow need only be bent to shape and worked to the desired cross section. Three types of wing bow cross sections are shown in figure 121.

b. Repair.—A wing tip bow which has been extensively damaged should be removed and replaced. A cracked or broken bow may be repaired by splicing in a new piece (see fig. 120). In this case a new piece has been spliced in at the spar. The new piece should have the same contour as the original bow and the splices should conform to all the requirements of a scarf joint (see par. 55).

60. Plywood skinning and skin repair.—*a. Application of plywood skin.*—(1) Plywood for the skin is first cut and shaped to fit the surface to be covered, allowing sufficient material for scarfing where necessary. In some cases, such as covering wing tips, it is necessary to cut the skin somewhat larger than is needed and trim it to size after it has been glued to the frame. The plywood is then temporarily nailed to the frame in one corner, adjusted as necessary, and nailed in the opposite corner. The nails should be driven through small strips of wood so they can be easily removed. After securing the corners, the plywood is pressed down against the framework with the hands to make sure that it is in the exact position and contacts the supporting members (ribs, spars, etc.) properly. If correctly located, the plywood is lifted and glue applied to the supporting members in preparation for attachment.

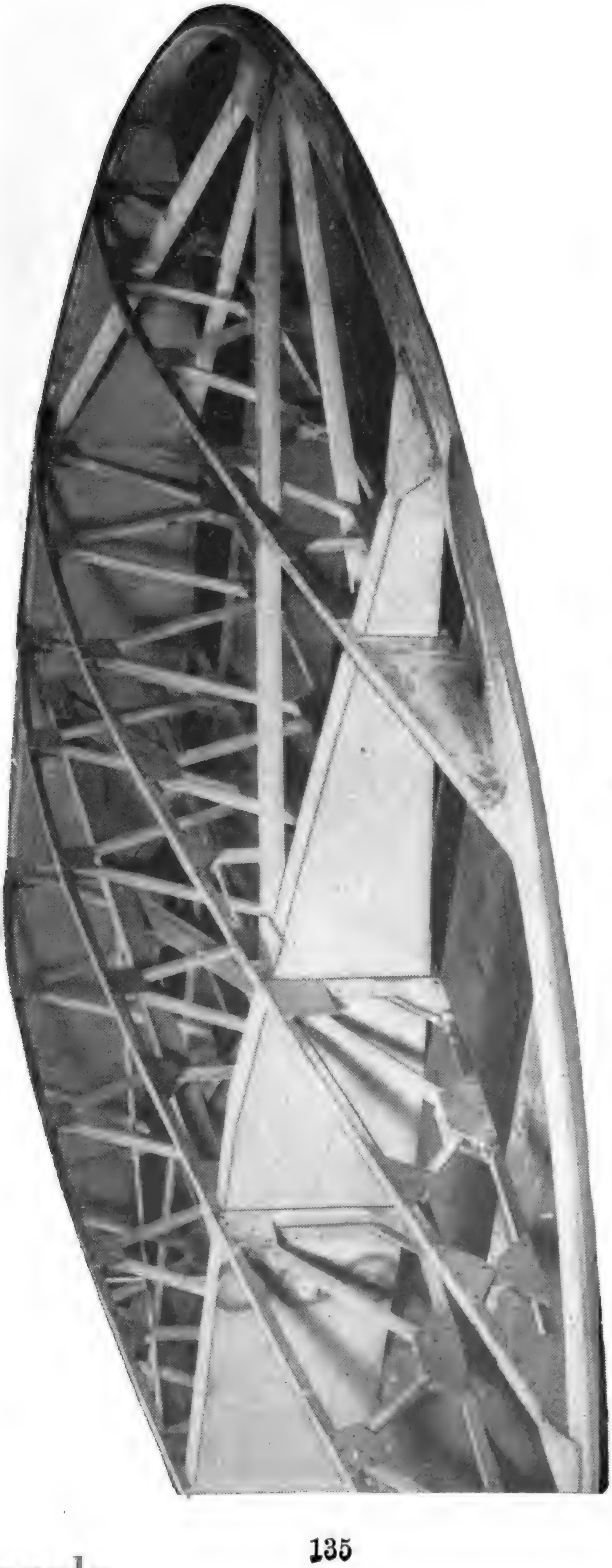


FIGURE 120.—Finished wing tip bow.

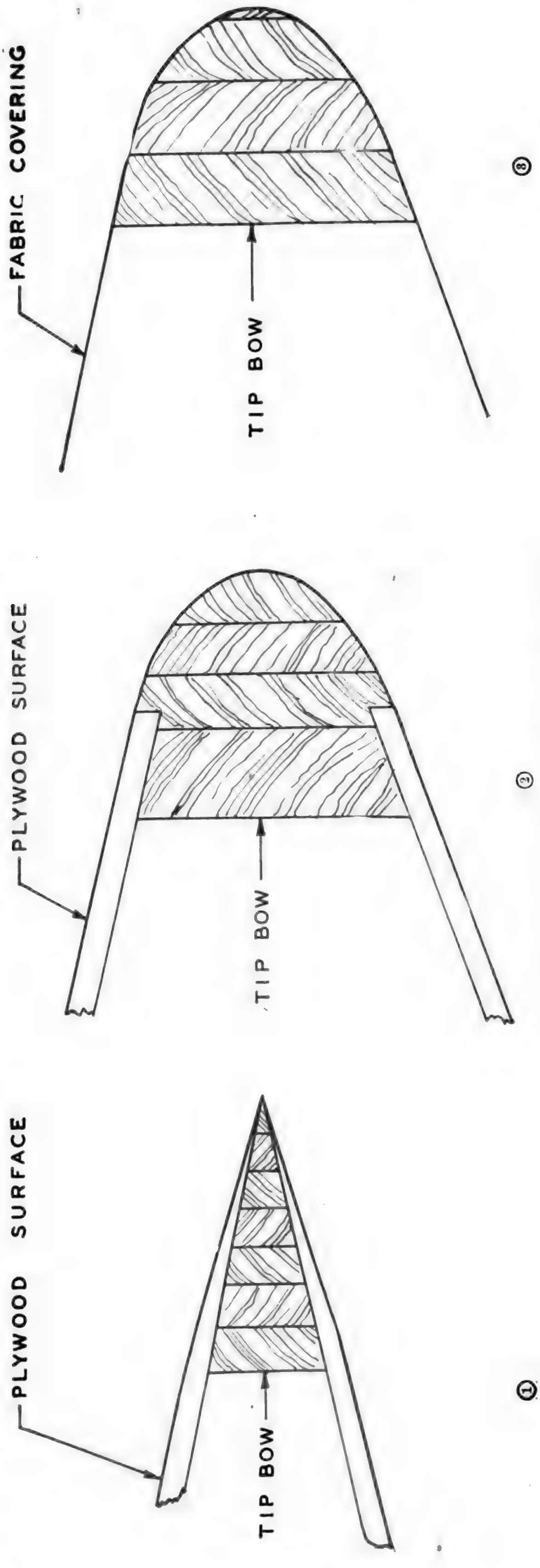


FIGURE 121.—Wing tip bow cross sections.

(2) Strips of wood usually 3/16 to 1/4 inch in thickness and 1/2 inch in width (nailing strips) are used to hold the plywood in place until the glue sets. Application of nailing strips is started near the center of the skin panel and nailed outward each way. Other nailing strips are then applied perpendicular to the first, beginning near the middle and working outward in whichever direction best avoids wrinkles and permits the plywood to lie smooth. The nails should be driven down tightly and enough nailing strips applied to cover the entire surface of the supporting members. The width of the supporting member always determines the number of nailing strips to be used. Surfaces 1/2 inch in width are covered with one nailing strip; wider surfaces are covered by nailing several strips side by side. The nails in one strip should be driven alternately with respect to those in the adjacent strip. For holding plywood skin 1/16 to 3/32 inch in thickness to the ribs, 5/8-inch nails spaced at 1 1/2-inch intervals are recommended. In general, close spacing of nails is preferred providing splitting of one or the other parts being glued does not result. It is important that wax paper be placed under the nailing strips where they come in contact with the glue to prevent the strips from being glued to the member. Figure 122 shows an application of nailing strips.

b. Covering a leading edge.—Plywood, cut to the approximate size of the section to be covered, is softened by soaking it in warm water (usually about 20 minutes), after which one edge is temporarily tacked along the top of the front spar. The plywood is then bent over the nose ribs, pulled down tightly, and held in place until thoroughly dry. Shock cord wrapped tightly over the plywood will serve to hold it in place. After the plywood has dried, the formed piece is refitted and cut to exact size. Glue is then applied to the framework (nose ribs, spar, etc.) and the formed plywood attached by means of nailing strips applied wherever the plywood comes in contact with the supporting members. Application of the nailing strips may be started either along one edge of the spar or along the leading edge strip. Other nailing strips are then applied over the nose ribs, starting with the center rib and working toward each end of the wing section. The nailing strips to be applied over the curved portion of the leading edge should be soaked in warm water to facilitate bending.

c. Covering exposed edges.—The exposed edges of plywood surfaces are usually covered with pinked edge fabric to prevent separation of plywood sheets and the loosening of the end grain of the plywood.

FIGURE 122.—Use of nailing strips.

d. Plywood patching.—Extensive repairs to damaged stressed skin of plywood structures should be made in accordance with specific recommendations from the manufacturer or Technical Orders. If the damage is very extensive, repairs are usually made by replacing the entire panel from one structural member to the next. Where holes are large, the seam should be made to lie along a bulkhead or along a structural member.

(1) *External patch.*—This type of patch (fig. 123), although easiest to make, is not recommended for wing, fuselage, or other surface repair where smooth surfaces are essential for proper air flow. It should be used as an emergency repair only. The patch is made as follows:

(*a*) Trim the edges of the hole until a smooth outline is obtained. The trimmed hole should not exceed 3 inches across in any direction for this type of patch.

(*b*) Remove all grease, varnish, dirt, etc., from the surface to which the patch is to be glued.

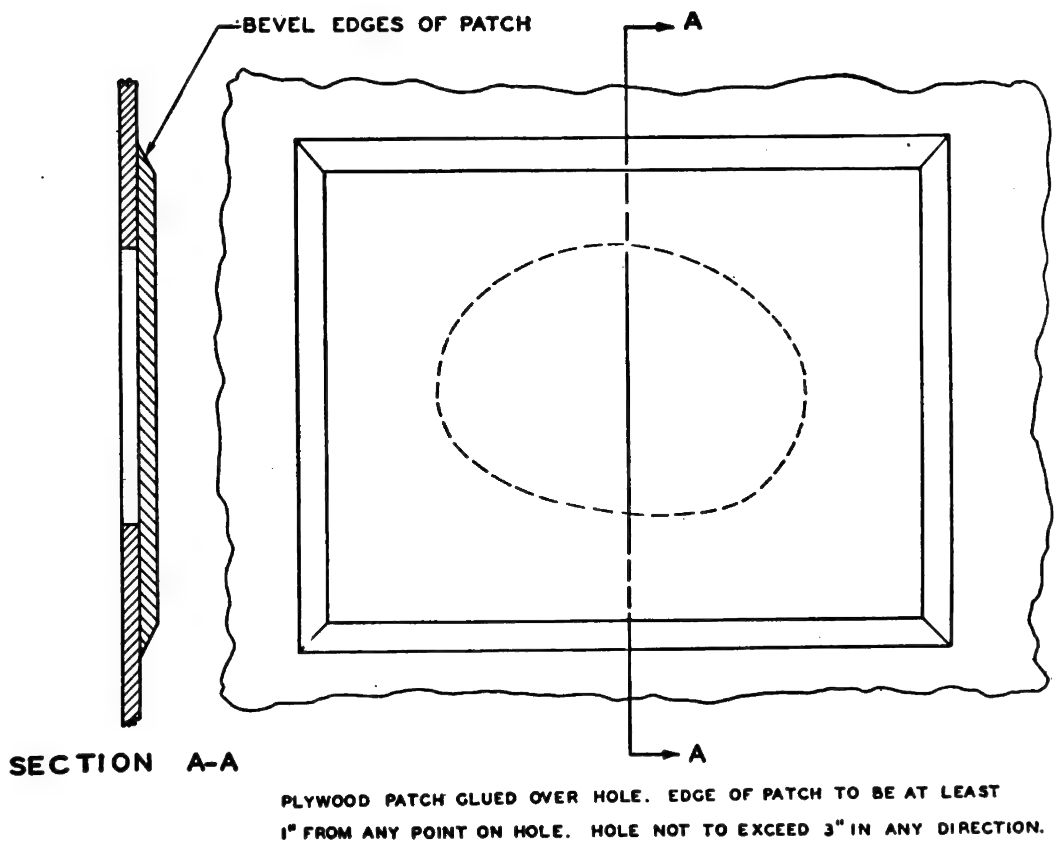


FIGURE 123.—External patch.

(*c*) Cut a piece of plywood, of the same thickness as the original cover, large enough to extend at least 1 inch from any point on the edge of the hole.

(*d*) Bevel edges of patch.

(*e*) Glue in place. (Use nails to hold patch until glue sets.)

(*f*) Sand patch smooth and finish to match surrounding surface.

(2) *Flush patch.*—This type of patch is used on wing, fuselage, and other plywood surface coverings. The edges of the flush patch are either scarfed or squared.

(*a*) The general procedure for making a scarf joint flush patch is as follows:

1. Cut away damaged section, making the opening square or triangular in shape. Where practical, one or more sides should be adjacent to a structural member (fig. 124).

2. Construct a frame of wood (spruce or other soft wood) to reinforce the unsupported sides of the hole. The inside dimensions of the frame should be the same as those of the opening, and the width of each strip should be 10 times the thickness of the plywood covering. Glue the frame to the skin, bracing it adequately or clamping it to the structure until the glue sets.

3. Scarf the edges of the opening in the skin over the reinforcing frame.

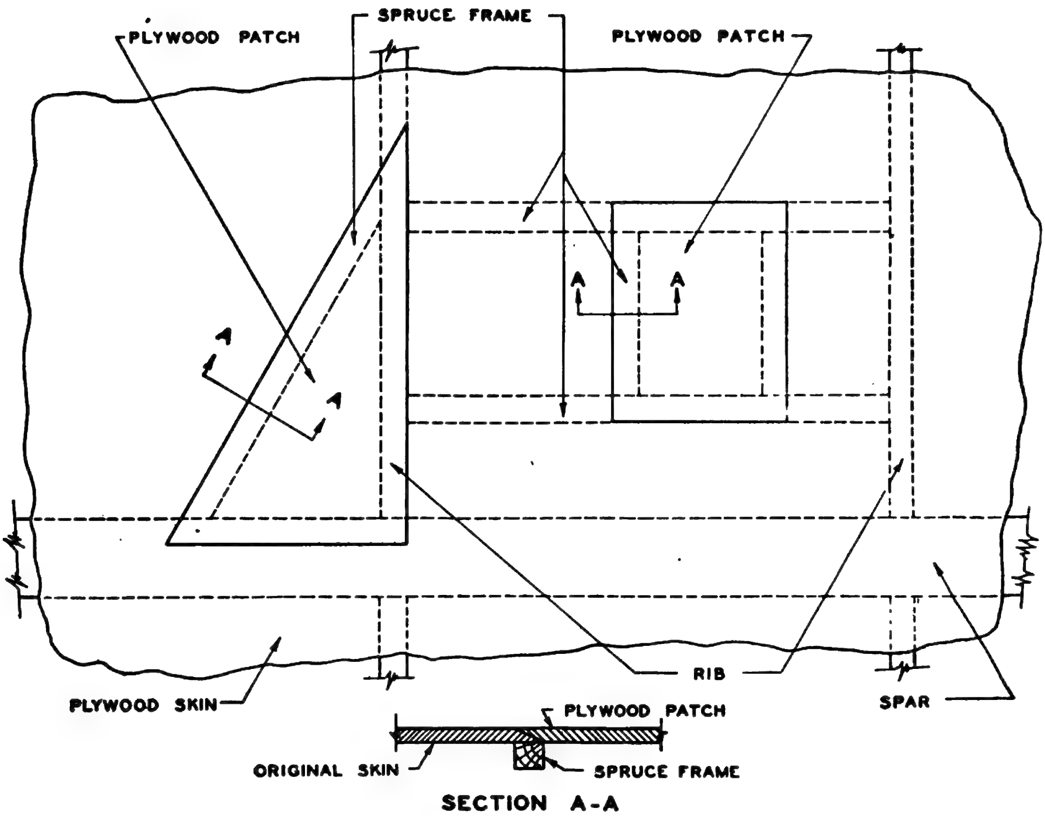


FIGURE 124.—Preparing skin for flush patch.

4. Cut a piece of plywood, identical in thickness to the original cover, the shape of the over-all opening. Scarf the edges to fit, and then glue and nail the patch in place (fig. 125).

5. After the glue has thoroughly set, sand the patched section and finish to match the surrounding surface.

(*b*) The general procedure for making a squared edge flush patch is as follows:

1. Trim damaged area to shape of a square or triangle, as previously described.

2. Construct a frame to extend over inner edge of hole to form a bearing surface for the patch. Glue frame under opening (fig. 126).

3. Make patch exact size of hole and glue and nail to frame.

4. After glue has thoroughly set, sand patched section and finish to match surrounding surface.

(*c*) When it becomes necessary to gain access to the interior of the wing panels where openings are not already provided in the cover, it is advisable to locate the cut-outs adjacent to members of the wing frame. The cutaway section should be limited in area as much as possible and closed when the work is finished by the same method as indicated above for making repairs. It is often possible to simplify the work and to reduce the area of the opening required by making the cutaway section triangular in shape.

61. Replacement of fiber insert self-locking nut plates in wooden members.—At various points in the fuselage and wings, fiber insert nut plates are installed for the attachment of such parts as fuel tank cap covers and inspection doors. Should one of these nuts be damaged or a machine screw break off in it, the portion of the strip carrying the nut and extending approximately 1 inch on each side should be sawed out and a new section (made locally) installed by gluing and nailing. These nut strips consist of 3/8-inch plywood strips with the nuts imbedded in them at regular intervals. A 1/16-inch-thick plywood strip is then glued and nailed over the nuts and drilled on correct centers to permit passage of the machine screws. This method permits of a much more reliable attachment of the nut plates than the use of wood screws.

62. Wooden propellers.—*a. General.*—(1) A propeller may be described as a twisted airfoil of irregular plan form. Damage to the blade surface will affect its efficiency and strength. Wooden propellers are built up of glued laminations of birch, mahogany, or wal-

FIGURE 125.—Application of flush patch.

nut. They are commonly metal tipped with brass, monel metal, stainless steel, or the equivalent. A linen fabric is frequently applied to the surface for additional strengthening at the tip and for protection against abrasion and splintering.

(2) Wooden propellers should be inspected for such defects as cracks, bruises, scars, warp, oversize holes in the hub, evidence of glue failure and separated laminations, sections broken off, and defects in the finish. The tipping should be inspected for such defects as looseness or slipping, separation of soldered joint, loose screws, loose rivets, breaks, cracks, eroded sections, and corrosion.

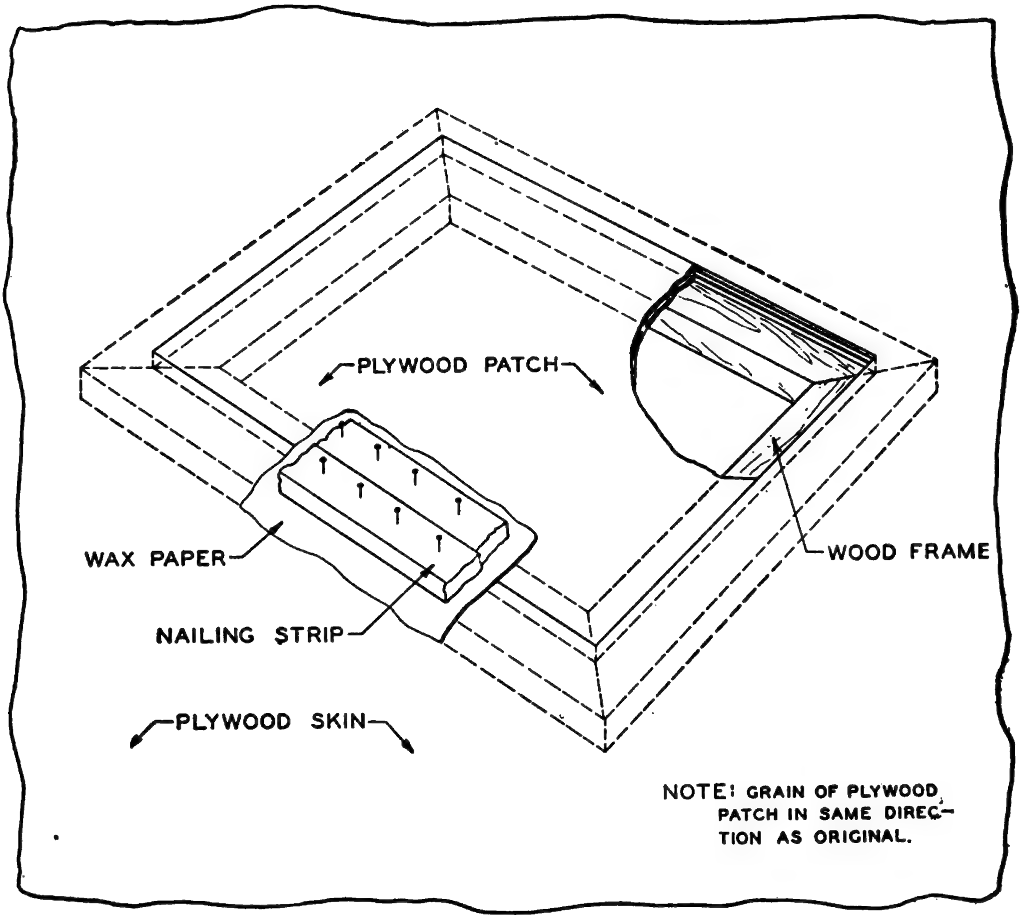


FIGURE 126.—Preparation of plywood skin for attaching squared edge flush patch.

(3) A wooden propeller damaged to the following extent should be scrapped:

(*a*) A crack or deep cut across the grain of the wood.

(*b*) A comparatively long, wide, or deep cut parallel to the grain of the wood.

(*c*) A separated lamination.

(*d*) An excessive number of screw or rivet holes.

(*e*) An oversize hub or bolt hole, or elongated bolt holes. (Plugging and reboring of bolt holes is not permissible.)

(*f*) An appreciable warp.

(*g*) An appreciable portion of wood missing.

(*h*) A crack, cut, or damage to the metal shank of adjustable pitch wooden blades.

b. Repair.—(1) *Small cracks and cuts.*—Small cracks parallel to the grain of the wood should be filled with glue thoroughly worked into all portions of the cracks. After it has dried it is sanded smooth and flush with the surface of the propeller. This applies also to small cuts.

(2) *Dents or scars.*—Appreciable dents or scars which have rough surfaces or shapes that will hold a filler and will not induce failure may be filled with a mixture of casein glue and clean, fine sawdust thoroughly worked and packed into the defect. After the mixture has dried it is sanded smooth and flush with the surface of the propeller. In any case, all loose splinters should be removed.

63. Skis.—Fractured wooden ski runners will usually require replacements, but a split at the rear end of the runner the length of which does not exceed 10 percent of the ski length may be repaired by attaching (with glue and bolts) one or more wooden cross pieces across the top of the runner.

64. Wood aircraft finishing.—*a. Abrasives.*—(1) Abrasives for finishing wood and painted surfaces are generally garnet paper and aluminum oxide cloth. The ream garnet papers are furnished in 9- by 11-inch sizes with a grit range of from 8/0 (very fine) to 0 (medium) for the finishing papers, and 4/0 to 2 (coarse) for ordinary papers. Grit of roll garnet paper ranges from 2/0 to 3 (very coarse), and aluminum oxide cloth ranges from 5/0 to 1/2.

(2) The general procedure to follow in using garnet paper (or aluminum oxide cloth) for finishing is as follows:

(*a*) Use number 7/0 garnet paper for the final light sanding of the wood surface.

(*b*) Sand the primer coat lightly with number 7/0 garnet paper.

(*c*) Between each succeeding coat of varnish, enamel, or lacquer, sand lightly with number 6/0 or 7/0 garnet paper.

(*d*) The last coat of paint need not be sanded.

(3) When sanding plywood surfaces, use a fine grain garnet paper applied with a light, even stroke.

(4) The contours of sections which taper, such as tapered wings, are reduced and brought into true and uniform alinement by contour sanding. This is accomplished with a long block of wood to which a

strip of roll garnet paper is glued. The block is moved lightly over the sections, using a sidewise stroke.

b. Finish for wood surfaces.—(1) *Interior.*—Interior wood surfaces should be given at least three coats of clear spar varnish; or one coat of clear spar varnish followed by one or more coats of aluminum varnish brushed or sprayed on. Surfaces which are likely to come in contact with fabric during the doping process should be treated with dopeproof paint, cellophane tape, etc., to protect them against the action of the solvents in the dope. Zinc chromate primer may also be used as a dopeproof coating.

(2) *Plywood coverings.*—Plywood coverings for wings, fuselage, and other surfaces are finished as follows:

(*a*) One coat of liquid wood filler or priming varnish. (Spar varnish thinned with turpentine may be used.)

(*b*) One coat of aluminized varnish.

(*c*) Two coats of oil enamel in accordance with color requirements. (Pyroxlin base dopes or enamels must not be used in the finishing scheme for plywood.)

(3) *Mixing paints.*—For mixing of paints see supplement No. 1, TM 1-440.

(4) *Removing finishes.*—(*a*) The finish may be removed from any portion of the airplane by using the solvent toluol or other recommended solvent. To remove the finish, dampen a cloth with toluol and rub the surface to be cleaned until all the finish has been removed. This same procedure applies to finishes on metal surfaces and fuselage interior, as well as to cleaning dope from exterior plywood surfaces after fabric has been removed. Toluol is highly inflammable and must not be used where there is danger from flame or spark.

(*b*) Carbon tetrachloride may be used as a solvent in place of the toluol, but it is not quite as efficient.

495091°—43——10

INDEX

INDEX

INDEX

[A. G. 062.11 (11-2-42).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

DISTRIBUTION:

R and H (2); Bn and L 1 (4); IBn 1 (10), 5, 9, 10 (2); IC 5, 9, 10 (2)

(For explanation of symbols see FM 21-6.)

U. S. GOVERNMENT PRINTING OFFICE: 1943